Final Report

VALUATION OF REDUCTIONS IN HUMAN HEALTH SYMPTOMS AND RISKS

Volume 2

COMPARATIVE ANALYSIS OF APPROACHES TO VALUING HEALTH RISKS

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VALUATION OF REDUCTIONS IN HUMAN HEALTH SYMPTOMS AND RISKS

This is Volume 2 of a four volume report. The total project undertakes an assessment and reconciliation of attempts to value reductions in human health risks, and it develops new methods and estimates for these values. Volume 2 contains a comparative assessment of work on valuing health risks. Based on the assessment, a set of interim morbidity and mortality values applicable to effects of criteria air pollutants is developed. Volume 3 reports on a study developing and applying contingent valuation techniques to the types of light symptoms often attributed to air pollution. Volume 4 reports on the design of approaches for valuing serious or life threatening illnesses.

Abstract of Volume 2

COMPARATIVE ANALYSIS OF APPROACHES TO VALUING HEALTH RISKS

Following the introduction to Volume 2, section 2.2 presents a model for valuing health risk reductions which can be used to compare alternative approaches to valuing health risks. Plausible assumptions imply that cost of illness and preventive expenditures measures are lower bounds to willingness to pay for health risk reductions. Contingent valuation, hedonic measures and other valuation approaches are compared conceptually.

Section 2.3 gives a critique of econometric evidence on the effects of environmental quality on human health. One of several concerns with comparability and reliability is how estimates are affected by avoidance measures taken by individuals in response to adverse environmental conditions. The assessment considers in detail five major empirical studies of the effects of air pollutants on mortality.

Section 2.4 is concerned with the cost of illness approach to measuring health benefits. A contribution of the present project is to put estimates of the aggregate cost of illness (medical expenditures and foregone earnings) due to morbidity on an individual per case and per day spent ill basis. Section 2.4 includes an evaluation of previous cost of illness studies.

Section 2.5 is concerned with contingent valuation studies in which interview estimates are obtained of willingness to pay for health. The three major existing contingent valuation studies of morbidity are evaluated.

In Section 2.6, a comparison is conducted of cost of illness and contingent valuation benefit measures obtained for a group of individuals for a common set of symptoms. The results indicate that willingness to pay as revealed through contingent valuation greatly exceeds cost of illness. The two measures do not move

together in any systematic fashion,

Section 2.7 considers the household production approach, in which the individual produces health by combining his own time and effort with purchased goods. Two studies are reviewed that use this framework to produce illustrative empirical estimates of willingness to pay for health improvements.

Section 2.8 reviews the housing market hedonic literature throwing light on housing price premiums for air quality. Estimates from this literature are used to obtain suggestive upper bound estimates of the value of mortality risks.

Section 2.9 brings together the foregoing results to arrive at a set of health risk values for use in environmental assessments. Interim values applicable to air pollution are developed, High, low and medium estimates are developed for morbidity conditions and mortality. Medium estimates of the value of reducing various types of acute or short term morbidity range from $25 to $125 per day. Medium estimates of the value of reduced aggravation of previously existing chronic morbidity conditions range from $60 to $150 per day. Medium estimates of the value of reduced new incidence of chronic morbidity conditions range from $800 per year for uncomplicated angina to $60,000 per year for non-fatal cancer. The medium estimates for mortality range from $2 million for an unforseen instant death to $4 million for a death due to lung cancer.

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2. COMPARATIVE ANALYSIS OF APPROACHES TO VALUING HEALTH RISKS

2.1 INTRODUCTION

A wide variety of approaches to valuing health risks or the benefits of health improvements have been proposed and in many cases implemented. Though this work has been reviewed, there is a continued need for a comparison of the various approaches, on both a theorectical and an empirical level. In particular, while the special case of valuing mortality risks alone has received a good deal of attention, the problems of valuing morbidity risks alone, or of valuing the more general case of a combination of morbidity and mortality risks has received less attention. The goal of Volume 2 is to provide a comparative review of approaches to valuing changes in health, and a synthesis of the empirical results of the various approaches..

In the next section, competing approaches are defined and briefly reviewed, but the main result is the development of a model of health investment which yields a general expression for the value of changes in risks to human health. Thus section 2.2 serves as an introduction to, and a conceptual framework for, the remainder of the volume. The contention that costs of illness and preventive expenditures are lower bounds to the preference based willingness to pay measure is carefully examined. In addition, the section explores the relationship between the value of a certain change in health, and the value of a change in health risks.

In the remaining sections, the theoretical justification and empirical results of the particular approaches are examined at greater length. The general goal of these sections is to discover what empirical estimates of the value of health exist, and to assess how accurate and complete these value estimates are likely to be.

Section 2.3 reviews health econometric results on the relationship between air pollution and health. These studies may shed light on the structure of the demand for health, and the role of avoidance practices undertaken by individuals in response to poor environmental quality. If so, the results will have important implications for measuring the benefits of improved health due to air quality improvements.

Turning to studies that have been explicitly concerned with placing monetary values on illness, section 2.4 reviews the cost of illness approach. This is the most widely usedmeasure of the value of health. Estimates from existing aggregate cost of illness studies are put on a per case of illness or per day of illness basis, to be comparable to what an individual would be willing to pay. In this way, estimates of the value of a range of health effects are developed that can be used to evaluate environmental policy changes. A careful review of the conceptual and empirical backgound of the cost of illness approach is also undertaken.

Section 2.5 examines the results of the limited number of studies that apply the contingent valuation method to valuing morbidity. This section includes the new results from the contingent valuation experiment discussed in detail in Volume 3 of this report. Consideration is given to the questions of how accurate estimates from contingent valuation may be, and to how results from the different studies compare.

Since the cost of illness approach and contingent valuation are probably the most important methods currently used to value morbidity, Section 2.6 reviews the available evidence on how these two methods compare. The most conclusive evidence on this question is from the data collected in the contingent valuation experiment of Section 3. Section 2.6 uses these data to test the hypothesis that a cost of illness measure is a lower bound to willingness to pay as revealed by contintent valuation.

Section 2.7 draws out implications for the value of health from studies of the household production of health. While relevant work is extremely limited, two studies are reviewed that yield illustrative empirical estimates of the value of acute morbidity due to air pollution.

Section 2.8 reviews work relating property values to air quality. A number of conceptual and econometric issues that have yet to be totally resolved are examined. Following this discussion, the relationship between housing values and air quality is used to imply values for mortality risks.

Section 2.9 is a synthesis of the results from the previous sections. Based on what is known about the health effects of air pollution, and on what a complete estimate of the value of health would include, a framework for estimating the value of health is reviewed. Using this framework, a table of interim values for the morbidity and mortality effects due to air pollution is developed.

2.2. FRAMEWORK FOR VALUING HEALTH RISKS

In this section we develop a model of health investment which yields a general expression for the value of changes in risk to human health. The preference based values of morbidity risks and mortality risks are ex ante dollar equivalents of changes in expected utility associated with risk changes. The values of changes in morbidity risks and and mortality risks are related to two alternative measures, costs of illness and preventive expenditures, which are thought to be lower bounds on the value of risk reductions. We demonstrate that these alternative measures are not even special cases of the more general measure and that the size relationships among the three measures are complex. Also, we derive the relationship between willingness to pay for risk changes and the consumer surpluses associated with health changes which occur with certainty.

The section begins with a review of several approaches to valuing changes in risks which are currently in use. The model of health risk behavior is developed in Section 2.2.2. In Section 2.2.3 implications for benefit estimation of the benefit measure derived from the model are discussed and concluding remarks are given in Section 2.2.4.

2.2.1. Approaches To Valuing Health Risks

2.2.1.1. Cost of Illness

The traditional approach to measuring the benefits of improved health is based on avoidance of disease damages. The damage avoidance approach, which is the form used by health professionals and some health economists, is also referred to as the cost of illness approach or sometimes the earnings expenditure approach. The cost of illness approach relies heavily on the idea that people are producers i.e., human machines. Outlays for health services are seen as investments which improve people as productive agents and yield a continuing return in the future. The yield for improvements in health is the labor product created plus any savings in health care expenditures due to any reduction in disease (see Mushkin 1962. pp. 130 and 136). The costs of health degradation are the damages caused by the disease (or accident). The health expenditures made, the value of the resources used in supplying health care, are referred to as the direct cost of illness. The loss of labor earnings due to sickness and premature death, the value of the lost product of labor, is referred to as the indirect cost of illness. The value of health improvements is the sum of the reductions in direct and indirect costs of illness. i.e., the damages which will be avoided. Studies employing the cost of illness approach include Weisbrod (1971), Cooper and Rice (1976), and Mushkin (1979).

Several deficiencies in the cost of illness approach are recognized: (1) the indirect costs are zero for retirees, ful i

time homemakers and other people who do not work in the market, (2) an arbitrary decision must be made about forgone consumption expenditures, i.e., gross or net labor earnings, (3) individuals are viewed as having no control over their health or health care expenditures and (4) there is little basis in economic theory for the use of the costs of illness in benefit-cost analysis. An attempt has been made by Landefeld and Seskin (1982) to reformulate costs of illness values to more closely approximate a theorecticallycorrect measure, but their study primarily focuses on externalities and an approach more closely tied to individual optimization seems more appropriate. Section 2.4 below examines in much greater detail the cost of illness approach as a possible source of estimates of the benefits of health risk reduction.

2.2.1.2. Willingness to Pay in Contingent Markets

The absence of a market for health as such prompted consideration of direct questioning techniques to elicit willingness to pay for changes in health risks. Through a survey interview or laboratory experiment a hypothetical market is established, and individuals are asked to purchase changes in health directly contingent upon the existence of the market. Contingent valuation of mortality risks was pioneered by Acton (1973) in his study of heart attack treatment and has been used by Loehman (1979) et al. to value morbidity related to air pollution. Currently there is renewed interest in direct questioning because it yields conceptually correct values of health risk which are difficult to estimate using other techniques.

Contingent valuation is considered in detail in Volume 3 of this Report, and empirical results applied to the value of morbidity are reviewed in section 2.5.

2.2.1.3. Household Production of Health and Preventive Expenditures

While the cost of illness approach concentrates on damages or costs following the onset of illness, individuals can and do incur costs in efforts to prevent illness from ever occurring. In Grossman's (1972) model of consumption and production of the commodity "good health", individuals combine purchased goods such as medical care and their own time to produce health capital. Willingness to pay is the value ofhealthytime and is the sum of two terms: (1) the increment in labor earnings which is possible and (2) the monetary value of the gaininutility associatedwith better health. Thus, the household production model gives a conceptual foundation for the relevance of labor earnings (indirect costs) for morbidity, but it also implies that a preference-based value will depend on the costs of producing health (preventive expenditures) and a utility, or consumption, value. An example of the household production approach is Cropper's (1981) micro study of the effect of air pollution on days lost from work due to illness. To value the health changes

she multiplies the wage rate by a factor derived from a specific production function.[1] This study and a study by Gerking and Stanley (1984) are discussed in section 2.7.

The recognition that health is partly endogenous has also spawned the idea that health improvements permit a reduction in preventive expenditures and that the savings of preventive expenditures is the value of the health improvement. This general approach has been suggested as a way to measure the benefits of reducing pollution where the expenditures prevent not only damages to human health, but also damages to property and so forth. Courant and Porter (1981) characterize the literature as having reached a limited consensus that such expenditures represent a lower bound to the total costs of pollution, a conclusion they dispute.

In a recent empirical investigation, Smith and Desvousges (1985) find that households do make adjustments to reduce the risk of exposure to hazardous wastes through drinking water. In their sample of households in suburban Boston nearly thirty percent purchased bottled water regularly to avoid hazardous wastes, while smaller fractions installed water filters and attended public meetings as ways to reduce the risks. This study provides important evidence that averting or preventive behavior in response to pollution risks can be significant. However, the relation between preventive expenditures and the benefits of improved health has received little attention. We explore this relationship.

2.2.1.4. Willingness to Pay in Implicit Markets

One implication of household production models of health is that individuals will make expenditures of money and time to improve their health and reduce risks to their health. By observing people's behavior in well-developed markets for ordinary goods and services values can be derived for health, which is not traded explicitly. Much of this type of evidence comes from the labor market in the form of estimates of compensating wage differential for jobs with extraordinarily high risks to health and survival. Most of the studies focus on implicit values of changes in the risk of a fatal accident.

Consumption activity also can involve exchanges between health and safety and other desirables. Estimates of willingness to pay have been made based on analyses of residential housing site choice, automobile seat belt use, speed of travel on highways and cigarette consumption.[2] This work, like that in the labor market, has focused on mortality risk. Inherent in this methodology of estimating implicit values of health risks is that individuals know and perceive differences. in health risks associated with various jobs and consumption activity and that they can choose among various alternatives.

Theoretical and empirical problems in viewing housing markets as implicit markets for valuing health are examined in Section 2.8. Estimates from these studies are reviewed as well.

2.2.1.6. A General Framework for Valuation

At this point there appear to be two disparate approaches to valuation of health and risks: cost of illness perhaps inclusive of preventive expenditures, and willingness to pay. Research has proceeded using one approach or the other, but only limited effort has been made to compare and reconcile the approaches. A recent paper by Harrington and Portney (forthcoming) is noteworthy in that they show that for morbidity, under certain conditions, the cost of illness values will be a lower bound on the theoretically preferred willingness to pay values. Below we develop an eclectic model with endogenous health risks and derive the preference based values for changes in health risks. The model considers morbidity and mortality and allows the probabilities of various health states and survival to be influenced by preventive activity and exogenous factors such as environmental quality. Terms for preventive expenditures and costs of illness in the benefit expression are identified for purposes of comparison with the conceptually correct willingness to pay. The model provides a framework for comparing values of health risks estimated using various techniques.

2.2.2. Human Health Risk Reduction Benefit Model

Assume a person's utility depends on the consumption of goods and services and the state of health. Utility may be expressed as

$$u = U(C,q), \tag{1}$$

where U is utility, C is consumption and q is a vector of health characteristics.[3]

A person does not know with certainty, however, what his health will be, or for a given state of health, whether or not he will survive the period in question. In order to incorporate these uncertainties into the model, we specify probability of health characteristics and probability of survival functions. The probability density function for health characteristics can be represented as

$$h(q;X,E), \tag{2}$$

where X is preventive expenditures and E is any exogenous shift variable, such as environmental change. Thus, the health characteristic probabilities are not immutable, but rather are influenced by preventive measures chosen by the individual person and exogenous changes 'such as environmental improvement.

It is reasonable to assume that the healthier a person is, the greater are the chances of survival of a given period. In other words, probability of survival can be expressed as a function of health characteristics:

$$P = p(q), \tag{3}$$

where p is the probability of surviving the period.

A final element of the model facilitates comparisons with the cost of illness approach for valuing health risk reductions. When in poor health, a person incurs cost such as medical expenditures and earnings lost due to days not worked. These costs will vary according to the degree of illness malfunction that occurs:

$$Z = f(q), \tag{4}$$

where Z is the cost incurred as a result of illness malfunctions. These expenditures reduce consumption, and provide no utility on their own.[4]

In this framework, a person chooses preventive expenditures X, in order to maximize the expected value of utility given the following income constraint:

$$M - C + x + z, \tag{5}$$

where M is money income in the absence of any' costs due to illness malfunctions,[5] Preventive expenditures influence the expected value of utility in three ways: (1) X increases the probability of being in good health, therefore increasing utility if alive; (2) at the same time, increasing the probability of being in good health also increases the probability of being alive; (3) finally, by increasing the probability of being in good health, X expenditures decrease malfunction costs Z that can be expected, increasing the amount of income expected to be left over for consumption. These benefits must be weighed against the direct loss in consumption made necessary by the preventive expenditures.[6]

More, formally, the consumer's problem can be stated as

(6) Max E(U) = the integral from negative infinity to positive infinity of

[U(C,q)p(q)h(q;X,E)dq]

subject to the income constraint (5). Reexpressing the income constraint in terms of C and substituting it into (6), the consumer's problem becomes

(7) Max E(U) = the integral from negative infinity to positive infinity of

[U(M-X-f(q),q)p(q)h(q;X,E)dq]

where U, p, and h come from equations (1), (3) and (2) respectively.[7]

The integral in (7) gives utility under different health outcomes weighted by the probability of the various outcomes. Since utility always depends upon health, the situation could be described as a continuum of state dependent utility functions, the possible states being the possible health outcomes. Different attitudes toward risk are allowed for through the shape of each state dependent utility function. When utility is expressed as U(M-X-F(q),q), it becomes apparent that preventive expenditures X directly reduce the amount of income left over for consumption. The term p(q) in (7) adjusts utility by the probability of being alive. Assuming no utility if dead, U(M-X-f(q),q) p(q) gives expected utility conditional on the state of health. A more extended analysis might consider utility of heirs as affected by bequest. The density function h(q;X,E) weights expected utility by the probabilities of different states of health. The integration over health states thus gives expected utility for the period;

The model as described does not specify fully the mechanisms available to the individual to adjust to risk such as market insurance. The only opportunity the individual has is to make ex ante preventive expednditures X that change the probabilities of the different states. V. Kerry Smith suggests that another extension of this analysis could be to carefully describe what opportunities are availabe to the individual to adjust expenditures made in each state of the world. Though these opportunities could easily be made explicit in the present model. this section retains the simpler framework in order to make the comparisons between preventive expenditures, cost of illness, and willingness to pay for risk reductions more straight forward However, in general willingness to pay values are affected by the opportunities available to adjust to risk, so it is vital to not* the simplified framework used.

The problem also becomes more tractable if a single health outcome measurable as a zero-one condition is considered. An example is occurrence of a specified type of cancer as affected by environmental irritants. Another example is occurrence of traffic accidents due to poor visibility brought on by air pollution, provided the major cost is associated with frequency of accidents, all having about the same expected severity, rather than the severity of an individual accident being importantly related to the degree of visibility. Tissue damage from contact with pollutants, such as liver damage, is another example as long as the principle effect is absence of unimpaired functioning rather than the degree of malfunctioning being associated with the degree of pollutant level.

A damage function, as might be the case for ozone, where the degree of discomfort rather the presence or absence of discomfort is related to the level of pollution, requires a more extended analysis considering probabilities for more than two states of the world. Various degrees of symptoms along with their associated probability densities have to be considered rather than just presence or absence of symptoms. The integral in (7) would not simplify as it does in the case where there is only one malfunction state.

If health is a matter only of absence or presence of a deleterious condition, the probability density function $h(q;X,E)$ is discrete rather than continuous with probability concentrated at q-l for presence of condition and q-0 for absence of condition:

$$h(q;X,E) = H(X,E) \text{ if } q\text{-}l \tag{8}$$

$$h(q;X,E) = (1 - H(X,E)) \text{ if } q\text{-}0,$$

where $H(X,E)$ is the probability of the absence of the condition.

In this case, the person decides at the beginning of the period what his preventive expenditures will be and then takes the resulting chance of what the health outcome will be for the period. A long planning period can be considered by letting consumption expenditures, illness costs, and preventive expenditures be average discounted present values, with the probabilities associated with survival and health status being averages of shorter term probabilities, possibly allowing for cumulative exposure effects.

Because of the discreteness of q when health is a matter only of the absence or presence of a condition, the integral in (7) simplifies to a sum of two discrete states corresponding to q-0 and q-l. Using (8), the consumer's maximization problem is

(9) $$\text{Max } E(U) = U_0 P_0 (1-H) + U_1 P_1 H$$

where $U_0 = U(M-X,0)$ is utility if free of the disease

$U_1 = U(M-X-Z,1)$ is utility with the disease

$P_0 = p(0)$ is probability of survival if free of the disease

$P_1 = p(1)$ is probability of survival with the disease

$H = H(X,E)$ is the probability of contracting the disease.

Equation (9) states that the expected utility to be maximized is the sum of utilities in the absence and the presence of the deleterious health condition, weighted by the probabilities of contracting and not contracting the disease and of surviving. As can be seen from the expressions for U_0 and U_1, utility depends both on the presence or absence of the disease, i.e. there is state dependence. The income constraint has been substituted into the utility function just as in equation (7). In the discrete case, this constraint can be expressed as[8]

(10)
$$C = (M - X) \text{ if } q = 0,$$
$$C = (M - X - Z) \text{ if } q = 1.$$

Differentiating equation (9) with respect to preventive expenditures X and setting the result equal to zero gives the first order condition for a maximum:

(11) $$F = U'_0 P_0 (1-H) - (U'_1 P_1 H) - (U_0 P_0 H_x) + (U_1 P_1 H_x) = 0,$$

where U'_0 and U'_1 are the marginal utilities of income when q = 0 and q-l respectively, and H_x, the change in the probability of contracting the disease resulting from an extra dollar spent on prevention. The first two terms give the decline in expected utility due to decreased consumption when an extra dollar is spent on defensive measures. The last two terms give the rise in expected utility due to decreased probability of contracting the disease as a result of the extra dollar spent on prevention. The first order condition for a maximum is that the sacrifice of consumption given by the first two terms must just offset the gain from the reduced probability of contracting the disease given by the last two terms.

In order for the consumer to obtain a maximum, the second

derivative of the expected utility function with respect to preventive expenditures must be less than or equal to zero. This second-order condition can be expressed as

$$(12)\quad \text{delta} = -U''P_0(1-H) - (U''P_0H) - (U_1P_1H_x) + (U_1P_1H_{xx}) < 0,$$

where H_{xx} is the second partial derivative of $H(X,E)$ with respect to X, and U''_0 and U''_0 are the second derivatives of utility with respect to income when q-0 and q-l respectively.

2.2.3. Valuation Of Changes In Risks To Human Health

2.2.3.1. Willingness to Pay

Expressions for the marginal willingness to pay (WTP) for an exogenous reduction in health risks can be derived from this model. The totally differentiated expected utility function must be solved for the change in income thatwouldbe required to keep expected utility constant when there is an exogenous change. The individual would be willing to pay the negative of this compensating variation for the exogenous improvements in health risks.

$$(13)\quad dE(U) = [U'_0P_0(1-H) + U'_1P_1H]\,dM + [(-U'_0P_0(1-H)) - (U_0P_0H_x) - (U'_1P_1H) + U_1P_1H_x]\,dX + [(-U_0P_0H_E) + (U_1P_1H_E)]\,dE$$

As before, U'_0 and U'_1 are the marginal utilities of income when healthy and ill, respectively. Just as with the levels of utility, these marginal utilities may differ from each other for two reasons. First, the level of consumption is higher when healthy, because of the costs incurred when ill (Z). Second, the presence or absence of a condition directly enters the utility function.

Holding expected utility constant in equation (13) by setting $dE(U) = 0$, equation (13) can be solved for the WTP measure:[9]

$$(14)\quad -dM/dE = -[(U_oP_o - U_1P_1)/m]H_E - [1 + ((U_oP_o - U_1P_1)/m)H_x]\,dX/dE.$$

The numerator of the first term is the difference in expected utility when healthy and when ill. This is divided by m = $(U'P(1-H) + U'PH)$, which is a weighted average of the expected marginal utility when healthy and the expected marginal utility when ill, with the weights being the probabilities of being healthy or ill. Thus m can be interpreted as the expected marginal utility of income.

So far, the analysis has neglected the fact that individuals choose the level of defensive expenditures so as to maximize expected utility. Rearranging the first-order condition given by equation (11) yields:

$$(15) \qquad (U_o P_o - U_1 P_1)/m = -1/H_x.$$

The left hand side is familiar from the WTP expressions. As the dollar value of the difference in expected utilities when healthy and ill, it can be interpreted as the marginal benefit of defensive expenditures that reduce the probability of illness. The right hand side is the marginal cost of defensive expenditures.

Allowing the optimal choice of defensive expenditures as individuals adjust to the exogenous changes in health risks or the environment implies that equation (14) satisfies the first order condition. Substituting the first order condition as given by (15) into the WTP expression given in (14):

$$(16) \quad -dM/dE = HE/H, + [-1 + (H_x/H_x)]dX/ = H_E/H_x.$$

This simplification allows the WTP measure to be expressed independently of the non-observable utility function, but instead in terms of the health risk function H. In particular, equation (16) gives the WTP for a change in environment as a ratio of the marginal product of the environment in reducing health risks and the marginal product of preventive expenditures in reducing health risks. This result is very similar to the findings of others who suggest WTP for an environmental improvement can be expressed solely in terms of the production function (see Courant and Porter (1981), Harrington and Portney (1983), Gerking and Stanley (1984), and Needleman and Grossman (1983)). One obvious difference is that while in these models health is deterministically a function of the environment and defensive expenditures, in our model the probabilities of being healthy or ill are a function of these variables. Another difference is that our model considers mortality as well as morbidity.

Equation (16) is the basis for one approach to obtaining

empirical estimates of willingness to pay. In principle, the health risk function H(X,E) could be estimated, yielding the marginal products necessary to compute WTP. Gerking and Stanley (1984) use this strategy to estimate WTP for ozone reductions in a model with pure morbidity under certainty. (See section 2.7 for a discussion of this study). However, Harrington and Portney (forthcoming) and Maureen Cropper emphasize the difficulties in correctly estimating a health or health risk production function.

The fundamental problem with the health production function approach is that it is hard to identify and measure all of the inputs that affect health. Harrington and Portney point out that typical epidemiological studies only explain a small fraction of the total variation in illness, suggesting that a number of important variables may have been omitted. In estimating a health production function applicable to air pollution-induced morbidity, the health outcome would be acute respiratory illness and not general health status. This could make the empirical estimation even more difficult, since respiratory health is jointly produced with other aspects of health. Finally, equation (16) only holds as a marginal condition. Bockstael and McConnell (1983) show that it may also be very difficult to use the household production approach to estimate the value of non-marginal changes. All of these problems indicate that the health production function approach to estimating WTP may be of limited usefullness. Below, other estimation strategies are investigated.

To allow for a more intuitive interpretation, equation (16) can be rewritten recalling that $H = H(X,E)$

$$dH/dE = H_x(dX/dE) + HE \tag{17}$$

or rearranging,

$$HE = (dH/dE) - H_x(dX/dE).$$

Substituting this expression for the marginal product of the environment in reducing health risks into equation (16) we have

$$\begin{aligned} -dM/dE &= [(dH/dE) + H_x(dX/dE)](1/H_x) \\ &= (1/H_x)(dH/dE) - (dX/dE). \end{aligned} \tag{18}$$

Writing this benefit expression in terms of utility by using the left hand side of the equation (15) we have

$$-dM/dE = -[(U_oP_o - U_1P_1)/m](dH/dE) - (dX/dE). \tag{19}$$

This form of the benefit expression states that a person's WTP

for an environmental improvement can be expressed as the sum of two terms. The first term is the dollar value of the expected difference in expected utilities when healthy or ill multiplied by the change in health risks due to the change in the environment or other exogenous factor. The second term is the change in preventive expenditures resulting from the exogenous change.

Our model yields an expression for willingness to pay which is ex ante in nature, i.e., before it is known whether or not the individual is sick. The value is that amount of income we have to take away from both states to keep expected utility constant. The value is defined by:

$$(20) \qquad U_0 P_0 (1-H) + U_1 P_1 H - U(M-X - dM/dE, 0) \hat{P}_0 (1-H) - U(M-X-Z\ dM/dE, 1)\ \hat{P}_0 H = 0$$

where the ^ indicates the value of a variable after a change in E. In the context of uncertainty our willingness to pay, -dM/dE, is similar to an option price (see Smith (1983)), since it is a constant payment regardless of the state of nature that actually occurs. V. Kerry Smith points out that in the model described in this section, however, the framework in which individuals can purchase state contingent contracts is not fully specified, so it is difficult to restrict the payments to be constant across the states of nature. As explained earlier, the only opportunity for individuals to adjust to risk is the purchase of preventive expenditures. These features of the model mean that the willingness to pay measure, -dM/dE, may not be consistent with conventional measures of option price. The measure is nevertheless a valid ex ante compensating variation for changes in risk.

2.2.3.2 Comparisons to Preventive Expenditures and Costs of Illness

It seems natural to assume that people will pay a positive amount for an environmental improvement. This means that to keep expected utility constant in the face of an exogenous improvement in the environment, an individual's income would have to be reduced, i.e., $dM/dE < 0$ and positive willingness to pay is equal to - dM/dE. Inspection of the benefit expression given in equation (17) reveals that WTP could be positive if both terms, the utility value and the preventive expenditure value, are positive. Since the total derivatives, dH/dE and dX/dE, show how risk and expenditures change after optimizing behavior, however, the terms cannot be unambiguously signed. For the total derivatives the general and plausible results and accompanying conditions are summarized in Table 2-l.

TABLE 2-1: COMPARATIVE STATIC RESULTS OF THE HEALTH RISK MODEL

	General Result	Plausible Results	Sufficient Conditions for Plausible Results
Preventive Expenditures	$\frac{dX}{dE} \gtrless 0$	$\frac{dX}{dE} < 0$	$H_{EX} > 0$ and $(U_0P_0 - U_1P_1) > 0$ and $(U_0^1P_0 - U_1^1P_1) \geq 0$.
Morbidity Risk	$\frac{dH}{dE} \gtrless 0$	$\frac{dH}{dE} < 0$	$\frac{dX}{dE} < 0$ and $H_E > H_X \frac{dX}{dE}$. or $\frac{dX}{dE} \geq 0$.
Willingness to Pay and Preventive Expenditures [a]	$-\frac{dM}{dE} \gtrless -\frac{dX}{dE}$	$-\frac{dM}{dE} > -\frac{dX}{dE}$	$\frac{dX}{dE} < 0$ and $\frac{dH}{dE} < 0$
Willingness to Pay and Cost of Illness [a]	$-\frac{dM}{dE} \neq -Z\frac{dH}{dE}$	$-\frac{dM}{dE} \neq -Z\frac{dH}{dE}$ [b]	Many exist
Willingness to Pay and Preventive Expenditures - Pure Morbidity Case [a]	$-\frac{dM}{dE} \gtrless -\frac{dX}{dE}$	$-\frac{dM}{dE} > -\frac{dX}{dE}$	$\frac{dX}{dE} < 0$ and $\frac{dH}{dE} < 0$.
Willingness to Pay and Costs of Illness - Pure Morbidity Case [a]	$-\frac{dM}{dE} \neq -Z\frac{dH}{dE}$	$-\frac{dM}{dE} > -Z\frac{dH}{dE}$	$\frac{dH}{dE} < 0$ and $\frac{dX}{dE} < 0$ and $U(C,0) > U(C,1)$ and $U(Z)/\lambda^{**} > Z$

[a] Willingness to pay is equal to $-\frac{dM}{dE}$.

[b] It is implausible that $-\frac{dM}{dE} = -Z\frac{dM}{dE}$. A set of sufficient conditions for this result is $\frac{dX}{dE} = 0$, $U(.) \neq U(.,q)$, $U(.,Z)/\lambda^* = Z$, and $P_0 = P_1 = 1$.

Preventive Expenditures

Consider the expenditure response of the individual to a change in the environment, dX/dE. Using the first order condition, F, shown in equation (11) and the implicit function rule, its-follows that:

$$(21) \qquad dX/dE = - F_E/F_X = - F_E/delta$$

where delta < 0 from the second order condition given by equation (12). The sign of dX/dE then is the same as the sign of F_e. Differentiating F with respect to E we get:

$$(22) \quad F_E = (U'P - U'P) H - (U P - U P) H_{EX}$$
$$\qquad\quad 0\,0 \quad 11 \qquad 0\,0 \quad 11$$

which cannot be signed unambiguously. The implication is that dX/dE need not be negative in that preventive expenditures could increase with an environmental improvement. Nonetheless, under plausible conditions dX/dE will be negative. If HEX > 0, which is the case if H and E are substitutes, and if $(U_0P_0 - U_1P_1) > 0$, which is the case if expected utility when healthy exceeds the expected utility when sick, and if the difference between expected marginal utilities is small, then $F_E < 0$. If $F_E < 0$, then dX/dE < 0.

Change in Health Risk

The risk response to a change in the environment, dH/dE, depends in part on dX/dE as can be seen from equation (17). The sign of dH/dE is negative if dX/dE < 0 and if H_E is larger in absolute value than H_X dX/dE; the sign of dH/dE is also negative if $dX/dE \geq 0$. In other words, the sign of dH/dE is negative except' when dX/dE < 0 and, what seems to be unlikely, the direct effect (HE) is less than the indirect effect (H_E dX/dE). While it is possible that the indirect effect can dominate even where there is evidence of counterproductive exogenous changes, alternative explanations are offered as being more plausible, e.g. see Viscusi (1984).

The upshot of this discussion is that while the two terms in equation (19) taken together surely imply that a positive amount will be paid for an environmental improvement, it is not strictly true that the terms separately will each imply positive payments It is the case, however, that the payments for reductions in risk and preventive expenditures will be positive under the plausible conditions that X and E are substitutes and the direct effect of E on H dominating the indirect effect through dX/dE. Under these conditions the willingness-to-pay for an environmental

improvement is the sum of the utility value of the reduction in risk and the savings in preventive expenditures. Also under these conditions the savings in preventive expenditures, dX/dE, is a lower bound on willingness to pay. If the conditions described above do not hold, then dX/dE is not necessarily a lower bou-nd on WTP. Under no plausible conditions is dX/dE a special case of WTP.

Cost of Illness

On the basis of the benefit expression it is tempting to consider a value of exogenous improvement based solely on the costs of illness as special case of the general WTP measure. Indeed, there might appear to be conditions under which the expression approaches being a special case of WTP. For instance, if (1) defensive expenditures are nonexistent or unchanging, and if (2) health does not enter the utility function directly, the WTP expression shown in equation (19) collapses to the first term, and the difference in expected utilities when healthy and ill only reflects the reduced level of consumption when ill due to the costs of illness incurred, Z. Even with these severe restrictions, however,

$$(23) \qquad -Z\,dH/dE \neq \frac{U(M-X)P_0 - U(M-X-Z)P_1}{m^*}\,dH/dE$$

where $m^* = U'[P_0(1-H) + P_1H]$. For Z to equal WTP additional questionable restrictions are necessary. For example sufficient conditions are that (3) the monetary value of the utility of consumption be equal to consumption expenditures, $Z = U(Z)/m^*$, and (4) the probability of survival be equal to one, $P_0 = P_1 = 1$, see Table 2-l. In fact, there are no plausible assumptions which can be made to simplify the WTP measure to cost of illness. It is even less likely that WTP will equal Z*, the more commonly used cost of illness measure which excludes the value of lost nonwork time.

Morbidity Risk

For the sake of brevity and because considerable attention has been given to mortality risk in previous articles we focus on valuing changes in morbidity risks.[10] For the pure morbidity case, there is no possibility of death whether healthy or ill, so $P_0 = Pl = 1$. The general WTP expression, equation (19), simplifies to:

$$(24)\quad -\frac{dM}{dE}\Big|_{P_0 - P_1} = -\frac{U(M-X,0) - U(M-X-Z,1)}{m^{**}}\,\frac{dH}{dE} - \frac{dX}{dE}$$

$$= -\frac{U_0 - u_1}{m^{**}}\,\frac{dH}{dE} - \frac{dX}{dE}$$

where $m^* = U'(1+H) + U'H$ which is expected marginal utility of consumption for the morbidity case.

The relationship between WTP and preventive expenditures is again, as in the case of morbidity and mortality, complex in that neither is unambiguously larger than the other. Again, however, under similar plausible conditions dX/dE is lower bound on WTP; see Table 2-l.

As in the case of morbidity andmortality there is no reason to believe that WTP equals the savings in costs of illness, - Z dH/dE. Plausible conditions do exist however, under which - Z dH/dE is a lower bound on WTP. If $dH/dE < 0$ and $dX/dE < 0$, then WTP > - Z dH/dE because Z dH/dE. One reason is that health enters directly in the utility function and utility is enhanced by health; U(C,O) > U(C,1). Another reason is that we expect the dollar value of utility lost due to losing Z dollars of consumption to costs of illness is less than Z. This relationship between the value of the utility of consumption and consumption expenditures, or labor earnings, has been explored in depth in the "value of life" literature. Conceptually it cannot be shown, strictly, what the empirical relationship should be, see Linnerooth (1979). Still, a representative theoretical conclusion is that the value of utility of consumption or earnings will "usually" exceed their dollar value; see Bergstrom (1982). Reviews by Blomquist (1981, 1982) and Violette and Chestnut (1983) of the estimates of the value of mortality risks are consistent with Bergstrom's conclusion. The implication for our case of morbidity is that U(Z)/m** > Z dH/dE. This relationship along with U(C,O) > U(C,1) lead WTP > - Z dM/dE. If also $dX/dE < 0$, then WTP exceeds - Z dH/dE by a greater amount. So, while we cannot definitely conclude that cost of illness measures produce a lower bound for willingness to pay, the lower bound conclusion seems plausible. These results are sumarized in Table 2-l.

2.2.3.3 Comparisons to Certainty Values of Morbidity

The willingness to pay expression in the pure morbidity case is shown in equation (24). The WTP holds expected utility constant in the face of an exogenous change in health risk. This

can be compared to measures of certain changes in morbidity as follows.

Define consumer surplus (CS) as the dollar amount which holds utility constant in moving from the certainly sick to the certainly well state. For an irreplaceable commodity such as health this measure is what Cook and Graham ((1977) call a "ransom." In terms of the model, CS is thus the difference between the utility in the healthy state and sick state $(U_0 - U_1)$ expressed in dollar terms by dividing by the marginal utility of income. The expected consumer surplus associated with an exogeneous change in the environment is the product of CS and the change in the probability of the certainly well state caused by the exogenous change:

$$\text{(25)} \qquad \text{Expected CS} = -\text{CS } dH/dE.$$

$$= -\frac{(U_0 - U_1)}{\text{(marginal utility of income)}} \, dH/dE$$

Comparing equations (24) and (25), it is clear that the willingness to pay for changes in morbidity risks given by (24) is almost the expected value of consumer surplus, adjusted for changes in preventive expenditures. That is, equation (25) is almost the first term of equation (24). The only ambiguity in this comparison is that in expressing the change in utility in dollar terms in equation (24), m**, the expected marginal utility of income or money is used. Since m** is a weighted average of marginal utilities when healthy and when ill, if we assume the marginal utilities are the same, the problem is resolved. In general, it is not clear when these two marginal utilities will be equal, since differences in consumption levels and health status are involved. The relationship between the marginal utilities of income across states also depends upon the opportunities the individual has to adjust expenditures across states. For instance, with actuarially fair insurance available the individual will equate marginal utilities across states, though this will not necessarily result in full insurance in the sense that levels of utility are equal across states (see Cook and Graham (1977)). In any case, if the marginal utilities of income across states are close to each other, willingness to pay for a change in health risks is approximately equal to the expected value of consumer surplus, adjusted for changes in preventive expenditures.

Consumer surplus is what previous studes which address the pure morbidity case have measured in their valuation expressions since they have avoided the question of uncertainty. The empirical work in Volumes 2 and 3 of this report also makes use of consumer surplus, In particular, since it is difficult to

appropriately incorporate uncertainty into the contingent valuation sxperiment, we measure consumer surpluses associated with certain changes in morbidity. However, we are able to approximate willingness to pay for risk changes by the expected value of these consumer surpluses as explained above.

2.2.4 Concluding Remarks

The main purpose of this paper has been to compare preference-based willingness to pay measures for human health risk reduction with the main alternative approaches that are currently in use. After providing discussions of the various approaches, we construct an eclectic model from which we derive preference-based (WTP) values for changes in health risks, which are then compared with the alternative approaches. The model incorporates partly endogenous health, uncertainty, mortality, and morbidity. In fact pure mortality and pure morbidity, to which previous studies have been confined, are considered as special cases of the more general framework.

In the general case, we find that the preference based willingness to pay measure for reductions in health risks consists of two terms: a utility term, which reflects the cost of ilness as well as other factors; and a term reflecting preventive expenditures. It does not follow, however, that benefit measures involving the cost of illness alone or preventive expenditures alone are special cases of our general willingness to pay measure. It is difficult or impossible to specify truly reasonable assumptions under which the willingness to pay measure collapses to a cost of illness measure or a preventive expenditures measure. Our emphasis is somewhat different from that of Harrington and Portney's in that their willingness to pay measure for a reduction in morbidity is reduced to the cost of illness measure under the assumptions that there are no preventive expenditures, and health does not enter the utility function directly.

Even the weaker result that the alternative benefit measures are lower bounds to the willingness to pay measure does not necessarily hold for our model. Without additiona. assumptions, we cannot establish any general comparisons between the three measures. We do find a set of plausible assumptions under which some comparisons of the alternative benefit measures can be made. First, it is necessary to assume that the environment and preventive expenditures are substitutes in reducing health risks. Second, the direct effects of a change in the environment on health risks must outweigh the indirect effects, so $H_E > (H_X)(dX/dE)$. Third, the marginal utilities of consumption when healthy and ill must be approximarely the same.

If the above assumptions are made, for the special cases of pure mortality and pure morbidity. both the cost of illness and the preventive expenditures will plausibly be lower bounds to

willingness to pay. The cost of illness approach understates the true willingness to pay for several reasons. First, it neglects the savings of preventive expenditures. Second, it does not allow for individuals to enjoy health directly, i.e., it implies in our formulation that health q does not enter the utility function.' Third, from the "value of life" literature it seems reasonable to conclude that the value of the utility of consumption will exceed consumption expenditures, so the utility lost due to expenditures lost resulting from cost of illness is greater than the cost of illness. It should be stressed that this result directly applies to the case of mortality, but would seem to be plausible for morbidity as well.

Preventive expenditures also are likely to be a lower bound to willingness to pay. The preventive expenditures are not a complete measure of the benefits of health risk reduction to an individual because the individual enjoys gains in expected utility as well as the savings of expenditures. Our model does not suggest any necessary relationship between the cost of illness and preventive expenditures measures.

One additional result is that the benefit of an exogenous change that improves both mortality and morbidity risks is not the simple sum of the benefits of mortality risk reduction and the benefits of morbidity risk reduction.

Our results'come from a model of individual maximizing behavior which considers the private costs and benefits. Thus, our results cannot be immediately generalized to social costs and benefits. However, we are able to draw some conclusions. For instance, we find in the case of pure mortality that private WTP and private cost of illness are unrelated since the latter does not matter to an individual if he dies. Only if we were to build in bequests, or to impose some constraint on the amount of debts thatcouldbe left at death, would costofillness enter the pure mortality framework. But we know costs of illness are not necessarily zero for society. So society's willingness to pay for a reduction in mortality risk may exceed the willingness to pay of the individual.

Empirical research on mortality risks has tended to confirm the prediction that benefit measures based on cost of illness will be lower bounds to benefit measures based on a willingness to pay approach. Further empirical work is needed to substantiate or refute the theoretical result that for morbiditv the cost of illness will be smaller than the willingness to pay Work.along these lines is reviewed in Section 2.6. In addition. future empirical work could shed some light on the case where both mortality and morbidity risks are present. Data which contain contingent value estimates of willingness to pav. estimates of direct and indirect costs of pollution related illness, and also pollution related preventive expenditures could be highly useful. These data would enable us to further investigate the questions examined in this section.

2.2.5 Footnotes

1. Cropper (1981) does obtain estimates of valuation of health changes, she does so only under very specific assumptions. Gerking and Stanley (1984) do so more generally, estimating the value of a change in health as the cost of preventive activity times an estimated ratio of marginal products of inputs in the heatlh production function.

2 For a review of labor market studies see Smith (1979). For a comprehensive survey of the literature on willingness to pay and fatality risks see Blomquist (1982).

3 C consists of both expenditures on market goods and services and on time, combined in fixed proportions. If the value of time is constant at the market wage rate, then consumption time expenditures are simply the product of the wage and the amount of time spent in consumption activities. Preventive expenditures (X) and costs of illness (Z) introduced below are also assumed to consist of expenditures on time and market goods combined in fixed proportions.

4 Typically, the cost of illness approach only includes earnings lost or the value of time lost from work and excludes the value of time lost from consumption activities. Define $Z^* = Z - c_L$, where c_L is the value of time lost from consumption. In our comparisons of the cost of illness and willingness to pay approaches in section 2.6 we will employ the more widely used Z* definition of the cost of illness.

5 M is the sum of nonlabor income and potential earnings. Assuming the wage rate is constant, potential earnings are simply the product of the wage rate and the total time in the period. The individual's problem can be expressed in terms of the choice of X, rather than its goods and time components, because of the fixed proportions assumption for X, C, and Z.

6. Just as with Z expenditures, X expenditures provide no utility directly by themselves.

7. Although the consumer's problem as expressed in equations (6) and (7) is single period in nature, it can be generalized to allow for multi-period planning as has been done by Crooper (1977). In particular,' suppose the probability density function, the probability of survival function, and the utility function all vary over time. Assuming an infinite planning horizon, the consumer's problem can be restated as

MAX E(U) = the integral from T to infinity of the integral

from negative infinity to positive infinity of

$$U(M_t - X_t - F(q_t), q_t; t)p(q_t, t)h(q_t, X_t, E_t, t)dqdt.$$

8. Note that for any given individual, Z is fixed once the disease is contracted. In a more extended analysis, Z could be made to depend on other variables such as the price of medical care. Z could be made endogenous in the current framework if it were specified as a function of preventive expenditures.

9. Terms involving the partial derivative of U with respect to q, disappear, since these terms are multiplied by dq, and dq = 0 since q is set at either 0 or 1. Similarly, recalling that the costs of illness Z are given by Z = f(q), dZ = f|(q) dq = 0, since again dq = 0.

10. Although we concentrate on morbidity risk we should note another implication of our model for the cost of illness approach. Typically COI studies separately estimate the morbidity costs and the mortality costs and simply add them together, e.g., see Mushkin (1979, p. 385). From our model it is evident that willingness to pay for combined morbidity and mortality risks is not the sum of the willingness to pay for the special cases alone.

2.2.6 References

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2.3. HEALTH ECONOMETRICS: AN ASSESSMENT

2.3.1. Introduction and Overview

The purpose of this assessment is to determine what the empirical evidence is with regard to effects of environmental quality on human health. The focus is on cross-sectional studies measuring the relationship between mortality rates and ambient air quality measures. A primary concern is whether or not these studies taken separately or as a whole can shed light on the structure of demand for health, not just net responses to changes in environmental characteristics on health measures. In this regard a fundamental consideration is the role of avoidance practices made by individuals in response to adverse health conditions in specification, estimation, and inference from econometric models. One reason for such concern is that impacts on health of differences or changes in climatic conditions, environmental quality, and other influences reflect the net effect of these differences after avoidance has taken place in response to what otherwise would have been adverse health effects.

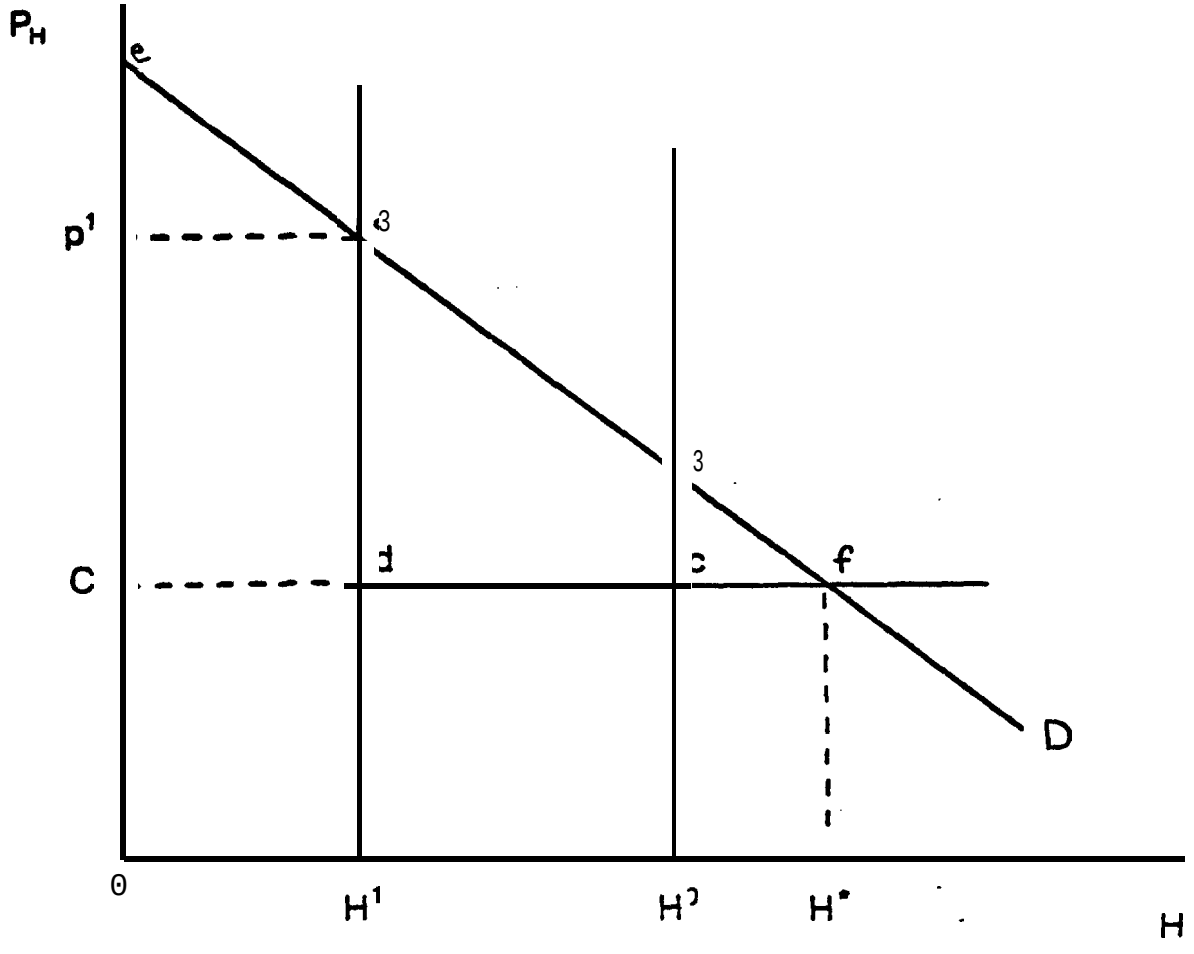
An illustration is presented in Figure 2-l where D is the demand for health, H, and there are two sources of health production: that from local amenity and environmental conditions and that produced by individual behavior. An extreme case is where with environmental quality Q_0 health status on average would be H^0 in the absence of other behavioral responses (e.g. defensive or avoidance measures). The supply of health from Q_0 is thus inelastic at H^0. At a similar extreme, suppose that avoidance procedures are perfect substitutes for environmental conditions and can be produced by an individual at constant cost C. Then, as depicted in Figure 2-l health status would be H* with defensive or avoidance expenditures given by $C (H^* - H^0)$. Consumer surplus is given by the area inside $oefcH^0$.

Now suppose that instead of Q_0, environmental quality was given by Q_1 which is less than Q_0. The supply of health from such conditions is now Hl which is less than H^0 yet the difference in health status can be offset by additional avoidance procedures at a cost of $C (H^0 - H^1)$. Consumer surplus in this case is given by the area $oefdH^1$ which is less than that previously by exactly $C (H^0 - H^1)$.

In the above example the correlation between observed health status (averaging H*) and environmental conditions would be zero even.though benefits of environmental improvements from Q^1 to Q^8 would be $C \times (H^0 - H^1)$. On the other hand, in a stochastic setting, regression of H^* (or more realistically, variations of actual health status around H^*) on Q and expenditures (or the level) of avoidance would result in biased estimates of causal effects of pollutants on health quality because expenditures are endogenous (affected by health status in their absence) However, controlling for the feedback effect (e.g. through use of instruments for health expenditures in the econometric

FIGURE 2-l

ENDOGENEOUS HEALTH AND ENVIRONMENTAL QUALITY



specfication of health status) the pollutant effect on health is essentially that which would occur without responding avoidance supply effects. In the extreme, the effect of an environmental quality change from Q^0 to Q^1 would lead to a change in health from H^0 to H^1, appropriately holding health expenditures constant.

More generally, differences in environmental conditions faced will be reflected in differences in health status even after avoidance procdures. The resulting calculation of benefits due to improvement in environmental conditions needs to consider not only cost savings (from a reduction in avoidance expenditures) but also the value of the increased health that would result.

With this in mind the assessment considers the results from five empirical studies of the effects of environmental pollutants on mortality: Lave and Seskin (1977), Crocker et al (1979), Chappie and Lave (1982), Mendelsohn and Orcutt (1979), and Schwing and McDonald (1976). The purpose of this assessment is not to duplicate the critiques of such analyses as presented in the EPA's "Air Quality Criteria for Particulate Matter and Sulfur Oxides." Rather it is to determine if estimated effects in these studies are robust in light of the ways in which avoidance and other measures are treated.

2.3.2 Study Summaries

L.Lave and E. Seskin, Air Pollution and Human Health (Baltimore: Johns Hopkins University Press), 1977.

This analysis compares mortality rates across 117 SMSAs in 1960 related to sulfates and particulates and 69 SMSAs in 1969 considering the effects of SO_2, NO_2, and NO3 also. Classical least squares estimation techniques are applied with control for effects of population density, percent of population over age 65, percent of non-white population, and the percent of households with income less than poverty level. Measure's of avoidance or defensive activities are not explicitly included.

T. Crocker, W. Schulze, S. Ben-David, and A. Kreese, Methods Development for Assessing Air Pollution Control Benefits, Vol. I. (Washington, D.C.: Environment Protection Agency) EPA-600/5-79-001a, 1979

This analysis compares mortality rates across 60 cities in 1970 and relates these to SO_2, TSP, and NO_2. Other exogenous variables included in the study are measures of population that was non-white, median age of population, living space density,

cold temperature, cigarette consumption, and three dietary variables. Also included as an explanatory variable is a measure of physicians per capita. An instrument for the latter was employed in estimation of the mortality rate specification in order to control for its potential endogenity with respect to mortality rates.

M. Chappie and L. Lave, "The Health Effects of Air Pollution: A Reanalyses," Journal of Urban Economics, 12 (1982), pp.346-376.

Data for 104 SMSAs in 1974 are employed in this analysis. Many variants of the previous Lave and Seskin model are examined which add to the set of control variables many dietary variables, as well as cigarette and alchohol consumption measures. In addition the effect of physicians per capita are examined (taking into account its potential endogeneity).

R. Mendessohm and G. Orcutt, "An Empirical Analysis of Air Pollution Dose-Response Curves," Journal of Environmental Economics and Management, 6 (1979), pp.85-106.

Mortality rates in 1970 for 404 county groups in the contiguous U.S. are examined in this study. Pollutants considered are sulfates, nitrates, SO_2, NO_2, CO, TSP, and Ozone. Many control variables are employed in estimating age-sex-race mortality rates. These include demographic characteristics for the age-sex-race group, the county group, as well as climatic condition and region specific characteristics. The estimation techniques is weighted least squares.

R. Schwing and G. McDonald, "Measures of Association of some Air Pollutants, Natural Ionizing Radiation and Cigarette Smoking with Mortality rates", in The Science of the Total Environment 5, (1976), pp.139-169. ------- -- ---

Mortality rates in 46 SMSAs in 1960 are considered in this study. The pollutants considered are SO_2, SO_4, NO_2, NO_3, and hydrocarbons. In total 23 explanatory variable (climatic conditions, pollutants, cigarette smoking. and natural ionizing radiation) are employed to study total and disease specific mortality rates. Three alternative estimation techniques are applied to these data: ordinary least squares, ridge regression, and sign constrained (with respect to pollutants) least squares.

2.3.3. Assessment

2.3.3.1. Pollutant Effect Comparison

Table 2-2 shows the effects of a 1 microgram/meter^3 increase- in various pollutants on the mortality rate (deaths/100,000) implied by estimates from the five studies outlined above, Comparison between studies of single pollutant effects are made somewhat difficult by the differences in the pollutants considered in any particular study. Correlation between included and excluded pollutants thus hamper the validity of inference based on effects of single pollutants. However, except for the estimates from Crocker, et.al. effects of sulfur oxides (SO_2 and SO_4 are positive and often substantial. The sign of effects of TSP are not consistent across studies. Except for the results in Mendelsohm and Orcutt, effects of Nitrogen oxides appear positive.

2.3.3.2. Study Design and Estimation Approach

Besides differences in the sets of pollutants considered in each study a variety of study design and estimation approach differences are relevant for assessment of these studies. A first consideration is that the Lave and Seskin and Mendelsohm and Orcutt studies do not control for such factors as smoking behavior or dietary characteristics of the population group considered. Correlation between these measures and the pollutant variables would serve to bias the estimated pollutant effects making serious inference from these two studies suspect. The Schwing and McDonald study suffers similarly from lack of inclusion of many of these potentially important variables.

The Chappie and Lave and Crocker, et.al studies, however, are very similar in that they include smoking and dietary varibles as well as consider the role of physicians per capita in affecting mortality rates. Yet, the implications for pollution effects differ substantially. To understand the reason for these differences more fully Table 2-3 presents the estimated coefficients on the other explanatory variables (for deaths/100,000) employed in these two studies. The demographic variables employed differ except for the percent of the population that is non-white. The coefficients on this variable are similar, andifthe piece of a package of cigarettes averaged slightly less than $1.00, the effect of population smoking characteristics is similar between these two studies. Effects of physicians per capita are also very similar between the two studies.

Substantially larger effects of per day protein consumption on mortality rates are found in the Crocker, et.al study compared to those in Chappie and Lave. Moreover, these effects are more precisely estimated in the Crocker, et.al. study. This suggests a potentially important influences of

correlation between dietary characteristics and the various pollutants considered in each study. Other than this, the reasons for the differences in pollution effects may be solely due to the difference between the effects of sulfates and the effect of SO_2.

2.3.3.3. Overall Design Consideration

Both the Crocker, et.al and Chappie and Lave studies address the endogeneity of physicians per capita on mortality rates within a cross-sectional setting. Such would be expected as demand for physician services may be one result of avoidance or averting behavior with respect to health problems. However, this is only one factor that may be important. Avoidance behavior may also be reflected in dietary, smoking, and alchohol consumption which needs to be seriously treated in further empirical work.

Avoidance or averting behavior in place, such as described above, is but one avoidance alternative. A second may be avoidance through changing residence location in response wo what would otherwise be adverse health conditions in an area. One implication of this would be that individuals may locationally sort themselves in accordance with differences in environmental quality among areas with those least affected living in relatively low quality areas. If such is the case, estimates of mortality rates differences between areas as a function of pollution would likely understate the effect of changes in overall pollution levels (especially those occuring in high pollution areas to begin with). Secondly, individuals may change location in response to what would otherwise be continued ill-health effects of pollution in one area. In such a case persons adversely affected by pollution might end up dying (and increasing the mortality rate) in low pollution areas. This would also lead to an understatement of the true effect of pollutants on mortality rates such as those based on the existing cross-sectional analysis.

Table 2-2

Estimated Effects of 1 Microgram Per Cubic Meter Increases in Selected Pollutants on the Mortality Rate

(Deaths/100,000)

Pollutant	Study					
	Lave and Seskin[a]	Lave and Seskin[b]	Chappin and Lave[c]	Crocker et.al.	Mendelsohm and Orcutt[d]	Schwing and McDonald[e]
so2		2.64		-.313	1.02	2.01
Sulfates (SO4)	5.418	-1.02	13.052		16.0	18.0
TSP	.619	-.022	-.322	.107	-.051	
NO2		.17	.082	-.082	-1.09	
Nitrates (NO3)		.035			-.059	2.3
CO(milligram/per cubic meter)					7.04	
03					.58	

[a] From Lave and Seskin (1977), Regression 7.1-3

[b] From Lave and Seskin (1977), Regression 7.8-10

[c] From Chappie and Lave (1982), Regressions 6-9

[d] Based on implied effects of 1 microgram per cubic meter change using estimates in Table III and pollutant means in Table Al in Mendelsohm and Orcutt (1979), 1970 age characteristics of the population for creation of adult population mortality rate effects.

[e] Schwing and McDonald present estimated elasticities of'pollutant effects on mortality rates. The estimates in Table 1 are based on elasticities for the pollutant at its primary standard level or, in the case of nitrates, at the average level presented in Mendelsohm and Orcutt (1979). Results are based on the constrained least squares elasticity estimates for total mortality rates given in Schwing and McDonald (1976).

Table 2-3

Comparison of Crocker, et.al. and Chappie and Lave Estimation Results (deaths/100,000)

Explanatory Variable	Crocker, et. al.	Chappie and Lave
Percent of population non-white	5.63 (4.56)	3.61 (3.47)
Median age of population	6.59 (11.54)	
Percent of households with greater than 15 persons/room	31.77 (2.35)	
Number of days with temperature below 0°	1.44 (2.91)	
Packages of cigarettes/year/ capita	2.2 (2.81)	
Per capita expenditures on smoking items		2.512 (1.92)
Per capita expenditures on alchohl		1.255 (2.45)
ln (population)		-42.59 (1.98)
Median family income		- . 036 (2.78)
ln (population/sq.mile)		41.98 (1.90)
Grams/day/capita of protein	70.1 (3.55)	8.42 (0.21)
Gram/day/capitaof carbo-hydrates	-2.92 (1.36)	.146 (0.20)
Grams/day/capita of saturated fatty acids	14.6 (1.45)	-2.222(0.12)
Physicians/10,000 population	-.53 (4.35)	-.64 (3.79)

2.3.4. Concluding Comments

All of the empirical findings cited in the studies reviewed in Section 2.3.2 suggest that pollutants can be related to measures of human health. The data sets employed and the statistical techniques employed differ, often substantially, in these analyses. Yet, one is very much left with the feeling that little is known regarding the relevance of the empirical findings for estimation of benefits of health status improvements associated with reductions in average pollutant levels, pollutant mix, or changes in pollution dispersion over, for example, a one-year period of time. One problem that arises is that multiple pollutants are often correlated in ambient air characteristics, which potentially reduces the information that can be gained regarding one particulare pollutant's impact on health isolated from those of other pollutants. This problem, however, is one that methodological approaches using ambient air quality measures can only hope to acknowledge and minimize using appropriate methods of inference from empirical results. Three more serious problems arise (some of which are addressed in the literature) which are of concern for current purposes. These are outlined below.

If the demand curve for health were known, in the extreme setting considered in Figure 2-l comparison of pollutant effects on mortality rates not holding constant and holding constant the endogeneous avoidance behavior of individuals in response to adverse health status should indicate the difference $H^0 - H^1$. Clearly, the health econometric studies examined do not yield reasonsable means of doing so. This information is quite useful in that it would allow for estimation of area H^1abH^0 if D were known. Indeed, the inf rmation that is missing but needed is an estimate of area H^1dcH^8, the amount of avoidance costs incurred to offset the decline in environmental quality. An important piece of information could thus be gained by regressing health avoidance costs (or at least those measurable) on environmental quality, giving an indication of this area. In more complicated avoidance cost situations where C is, for example, an increasing function of $(H - H^i)$ or shifted as a function of H^1, this type of avoidance cost information would still be needed in order to determine true benefits of pollution reductions. Regardless, structural estimates of not just the human health specifications are needed in order to get an appropriate measurement of the benefit function for reduced pollution. A need in this regard is thereby to investigate the opportunities available in estimating the full set of simultaneous relationships involved. Two potentially important areas in which to extend even further empirical analysis in this regard are discussed below.

2.3.4.1. Location Change Complications

In one very relevant sense, the level of pollution faced by an individual are subject to choice. Of relevance for current

purposes is whether or not individuals respond to ill effects of pollutants on 'human health (or health production) by migrating to areas with better environmental quality if they do and if past period pollutant experiences affect future health conditions, in an extreme case a negative partial correlation between current health status and currently faced environmental conditions is not only expected but is also a measure of the severity of the pollutant's impacts on health preservation.

Endogeneity of location choice and thus environmental quality means that feedback between current health status and current pollutant levels needs to be explicitly incorporated into health econometric studies. It is not sufficient to simply include a net migration variable into mortality or morbidity rate specifications. In any case, only health induced migration would be of concern regarding correlation of the migration measure and the error term in the health specification.

More generally, effects of exposure to pollutants may be lagged or cumulative. It is important to deal more adequately with exposures faced by individuals over longer periods of time (controlling for location changes) than has heretofore been attempted. This would be especially relevant in attempting to measure differences in impacts on health of fluctuation-s in environmental conditions and long-term differences in exposure.

2.3.4.2. Population Heterogeneity

Almost all of the health econometric studies acknowledge likely differences in effects of pollutants on individuals. In fact, even in its most random form where pollutants equally affect everyone's probability of a certain health effect, some individuals are spared the impact which others are not. Controlling for differences in measured demographic characteristics of the population allows for alleviation of some of the problems involved with heterogeneity in susceptibility. Still, the problem of heterogeneity in unmeasured characteristics poses a measurement problem.

One way of starting to deal with this is to consider measurement of changes in health status of a panel sample of individuals. Effects of pollutants may then be related to the actual health status of individuals in prior years to help address the question of susceptibility. In conjunction with this,the role of migration in response to deterioating health and its impact on location of, for example, death, relative to pollution levels could be more fully examined.

2.4. COST OF ILLNESS APPROACH

2.4.1. Introduction

The cost of illness (COI) approach focuses on those aspects of the value of health that may be fairly directly measured: medical expenditures and foregone earnings due to illness. The basic idea of many COI studies is simply to convey in some quantifiable way the impact of illness on the U.S. economy. These studies range from comprehensive studies of the cost of all illness in the U.S. for a given year to studies dealing with a specific disease or group of diseases. The COI approach is also frequently used as a way to measure the benefits of a program or any change that improves health, for use in benefit cost analysis. The reasoning is clear: if illness imposes the costs of medical expenditures and foregone earnings, a reduction in illness yields benefits equal to the costs saved.

Researchers have used the COI approach as away to value the health benefits resulting from a change in air pollution levels. For instance, Lave and Seskin (1976) combine their data with the Cooper and Rice (1976) estimates of the total cost of illness in the U.S. to find a value for a hypothetical change in pollution levels. This section is mainly concerned with using cost of illness estimates as a source for empirical estimates of the value of health effects linked to air pollution, though a fairly general appraisal of 'the approach is also undertaken.

The appeal of the COI approach is its seemingly straightforward estimation of clear, well-defined and observable quantities. There is a large amount of information collected on medical expenditures and foregone earnings due to illness, and the sources are often good quality, national data bases. Since the COI approach does not place a value on the more intangible aspects of health, notably pain and suffering, the approach is intuivively seen as estimating a lower bound to the true value of health. As alternative willingness to pay estimates for the value of reductions in mortality risks have become available, the COI approach is less frequently used to value these risks. However, alternative estimates for the value of morbidity are just becoming available, and the range of morbidity effects valued is still quite limited. The quality of the alternatives to COI values of morbidity is also questioned. For these reasons, the COI approach remains an attractive source of estimates for the values of a wide range of morbidity effects. In this section the COI approach is mainly applied to morbidity; mortality is discussed only incidentally.

A drawback to the COI approach as usually implemented is that it produces estimates of the total medical expenditures and foregone earnings due to illness in the U.S. However, the data linking air pollution to morbidity are on an individual basis. For example, air pollution can be related to the days an average individual spends ill inayear. There are two ways to conduct a benefit cost analysis of air pollution using aggregate cost of

illness estimates and individual links between air pollution and health. First, the data linking individual health effects and air pollution could be used to extrapolate the total amount of illness caused by air pollution in the U.S. This aggregate quantity of illness could then be valued using an existing COI estimate. (This is the procedure used by Lave and Seskin (1976)). An alternative route is to derive from the existing aggregate COI studies estimates of an individual's cost of illness. These individual estimates could then be directly combined with the data linking individual health effects and changes in air pollution. If the objective is to estimate the aggregate cost of illness due to air pollution, it would be necessary to make assumptions about the distribution of individuals and link them to the micro relationships. As V.K. Smith points out, this "bottom up" approach is probably intuitively more appealing to many economists. To implement this approach, estimates of individual cost of illness are required.

Estimates of an individual's cost of illness are desirable for several other reasons, The theoretical models that suggest cost of illness measures may be a lower bound to the conceptually correct measure of the value of health apply to individual and not aggregate values. In addition, alternative approaches to valuing morbidity produce estimates of an individual's value of health. At present, direct comparisons of these individual willingness to pay estimates and the aggregate cost of illness estimates can not be made.

The goal of this section is to express existing COI approach estimates on a basis that relates to what an individual would be willing to pay for a change in health. Section 2.4.5 puts a number of studies' estimates on a per case and a per day basis. This procedure is not necessarily ideal, since a "top down" approach is still used in estimating the individual's costs of illness: the process begins with the aggregate costs and uses these to imply the individual costs. This approach was originally proposed as a means to avoid serious double-counting of costs (Rice (1966)). Since the relative performances of the "top down" versus "bottom up" approaches is an open issue, some estimates based on individual observations of costs are also presented. Additional information on individual costs was obtained in the survey described in Volume 3, and reported in section 2.6 below.

Preceding the presentation of the empirical results obtained from existing COI studies (section 2.4.5), a general assessment of the usefulness of the COI approach is undertaken. Section 2.4.2 discusses the relationship between the COI approach and the conceptually correct willingness to pay approach. Section 2.4.3 extends this discussion to consider differences between individual and societal willingness to pay for health improvements. While this distinction is made in the context of the cost of illness approach, the difference between individual and societal values is important for all attempts to value the benefits of health improvements. Following these discussions of

conceptual issues, section 2.4.4 is a critical evaluation of the standard methodology of COI studies.

2.4.2. Linking the Cost of Illness Approach to Willingness to Pay

Researchers using the cost of illness approach have noted a number of shortcomings of the approach for benefit cost analysis. For instance, the COI approach makes no attempt to measure the benefits of reduced pain and suffering associated with health improvements, as noted above, but concentrates on more easily measured aspects of the cost of illness. Thus benefit cost analysis using this approach to valuing benefits may indicate that fewer resources should flow into cancer research, for example, than the public might desire because of the relatively high costs in terms of pain and suffering of cancer. (This example is suggested by Cooper and Rice (1976).) Another general problem is that little value is placed on activities outside of the marketplace, since the approach considers only foregone earnings. While recent studies have attempted to make adjustments to allow for value to be placed on the time of those individuals keeping house, leisure time in general, and thus much of the time of retired individuals in particular, is implicitly not valued at all. Programs that reduce the illnesses of the older members of society might be very difficult to justify using benefit cost analysis, if the benefits are measured using the COI approach. Programs aimed at improving the health of another segment of the population, the very young, may also show few benefits from the COI approach. Since future earnings are discounted, at a fairly typical discount rate of 10 percent earnings that start 20 years in the future have a relatively small present value. This list of troubling implications of benefit cost analysis using a COI approach could be extended, which suggests that the benefits of improved health that most people actually perceive may not be well estimated by the COI measures.

The fundamental problem with the COI approach is that though the quantities the studies estimate are clearly important aspects of the benefits of improved health, the methodology originally was not founded on any rigorous theoretical basis. This point is forcefully made by Mishan (1971), who particularly emphasizes changes in mortality risks -- the "value of life." He points out that benefit cost analysis is based on the proposition that an action is judged by whether it represents a potential Pareto improvement, that is, whether the gains resulting from the action can be distributed so that at least one person is made better off, and no one is made worse off. To use this criterion, it is necessary to look at the sum of what each member of society is willing to pay or accept for the change. The problem with the COI approach to measuring the "value of life" is that there is no a priori reason to believe that an individual's future earnings

will be related to his willingness to pay for a reduction in mortality risks. Studies based on individual preferences for such reductions are now usually said to follow the willingness to pay (WTP) approach.

In response to Mishan's and others' criticisms, a good deal of attention has focused on theoretically relating discounted future earnings to what an individual would be willing to pay for a small reduction in the risk of death. Two conclusions emerge from the theoretical work. First, there is no necessary relationship between future earnings and willingness to pay (see Linnerooth, (1981), or Rosen (1981)). Second, however, under certain restrictive conditions future earnings may be a lower bound to the willingness to pay measures. (Usher (1971), Conley (1976)).

Comparisons of empirical work following the COI approach to work following the WTP approach support both of these theorectical conclusions. Blomquist (1981) in his review of existing empirical studies concludes that while "there is no close association of value of life with future earnings....there is a strong indication that the value of life is greater than future earnings." Thus, there is some theoretical and empirical justification for one element the COI studies estimate: the foregone earnings due to premature mortality. It must be stressed that the justification is weak. At best, these foregone earnings are only a lower bound to the conceptually correct WTP measure, so there is no reason to believe the measures will be close to each other.

Much less attention has been paid to justifying the remaining elements of the COI estimates: medical expenditures, and foregone earnings due to morbidity. Ideally, the cases of mortality and morbidity should be considered together, to allow for possible interactions (see section 2.2). The expressions derived from such a model are fairly complicated, but it is possible to show that for the case of pure morbidity, under certain plausible assumptions, the cost of illness will be a lower bound to the WTP measure.

In short, theoretical models suggest that WTP reflects four components: 1) lost wages: 2) additional medical expenses; 3) the dollar-value of the disutility of additional illness; and 4) the change in defensive expenditures. This can be seen in the willingness to pay expression derived in section 2.2 for the case of pure morbidity:

$$(24)\quad -\frac{dM}{dE} = -\frac{U(M-X,0) - U(M-X-Z,1)}{P_0 - P_1}\,\frac{dH}{dE} - \frac{dX}{dE}$$

$$m^{**}$$

The first three components of willingness to pay for a reduction in the risks of morbidity are reflected in the expected difference in utility when healthy and when ill valued in dollars

(the first term on the right hand side). The difference in utility when healthy and when ill depends upon both the cost of illness term Z and the absence or presence of the condition (0 or 1 as the second argument in the utility function U). cost of illness Z is defined to include the value of time lost due to illness, reflecting both foregone earnings and the value of leisure time, and all the out-of-pocket medical expenditures necessitated by illness. Willingness to pay also depends upon the change in defensive or preventive expenditures brought about by the reduction in risks (the second term dX/dE). (For a more complete discussion and definition of all variables, see section 2.2.)

In contrast, the COI measure only includes the lost wages (often called the indirect costs) and the additional medical expenses (the so-called direct costs). The amount an individual would be willing to pay is largerthanthe COI measure as long as the omitted quantities of the WTP measure are positive. People will always pay a positive amount to avoid the disutility of illness. Whi'le Courant and Porter (1981) emphasize that defensive expenditures may either increase or decrease in response to an decrease in pollution, the normal cases is that a decrease in pollution saves defensive expenditures, and so these savings are a positive part of the WTP measure. In this case., the COI measure of the benefits of a reduction in morbidity is a lower bound to the theoretically correct WTP measure. However, as shown in section 2.2, there are no plausible conditions under which the cost of illness measure is a special case of WTP.

The theoretical model does not suggest how close the COI measure will be to the WTP measure. Rigorous comparisons of these measures are undertaken in section 2.5. Some idea of the difference between the measures can be gained by considering the aspects of benefits the COI measure neglects: the disutility of illness and the savings in defensive or preventive expenditures. While illness may decrease utility in many, possibly subtle, ways, probably the most important effect is the pain and suffering caused by illness. Mushkin (1979) attempts to estimate a dollar value on the total pain and suffering due to illness, basing her estimates partly on market revealed preferences, such as expenditures on painkillers, expenditures for medical care due to a pain symptom, and so forth, and partly on value's given to pain and suffering in court awards. Her estimates for 1975 range from $25.8 billion to $228.6 billion, compared to a traditional COI measure of $322.6 billion. That is, allowing for pain and suffering could represent an increase of 8 to 70 percent in the COI measures of the benefits of improved health.

Unfortunately, no comprehensive estimates could be found of the total defensive expenditures due to illness. The household production models of health (Grossman (1972)) do suggest that a wide variety of activities and goods may play a role in the production of health, so the change in defensive expenditures is possibly large. As reported below (section 2.6), as part of the contingent valuation experiment information was collected on

individuals' purchase of items for health reasons (air conditioner and humidifiers) and it was found that non-trivial proportions of the sample had made such purchases. In relation to pollution induced health risks, Smith and Desvousges (1985) find that households do make adjustments to reduce the risks of exposure to hazardous wastes through drinking water, but are not able to measure the value of these actions, This evidence indicates that the change in preventive expenditures may be a significant determinant of how much individuals are willing to pay for a reduction in health risks. Thus, consideration of the elements of the WTP measure the COI measure neglects suggests a tentative conclusion that the COI measure seriously underestimates true willingness to pay for an improvement in morbidity.

The general conclusion of the work comparing the COI approach to valuing improvements in mortality and morbidity to the WTP approach is that the COI benefit measure is a lower bound to the WTP benefit measure, but not necessarily a very good approximation of it. Almost all three elements of the COI measure can be related to what an individual would be willing to pay for an improvement in health: medical expenditures due to morbidity, foregone earnings due to morbidity, and foregone earnings due to premature mortality are all elements of a theoretically derived measure. The omission is that medical expenditures due to fatal illnesses have not been related to the willingness to pay for a reduction in the probability of such an illness. In a nonrigorous argument, this seems plausible, since an individual will not value these expenditures if he is not alive to pay them. The possibility of a bequest motive, though, implies that an individual does derive utility from his heirs' consumption possibilities, and so if the medical expenditures due to a fatal illness reduce the amount of the bequest, the individual may be willing to pay to avoid these costs. Other possible justifications for including the medical expenditures due to fatal illnesses arise from the consideration of societal, rather than individual, willingness to pay. The question is similar to the problem of whether "premature" funeral costs are of interest in valuing reductions in mortality risk.

A secondary problem stemming from the medical expenditures due to fatal illnesses is that in many studies where medical expenditures are used in benefit cost analysis, all medical expenditures are implicitly asumed to be due to morbidity. The impact of this incorrect assumption is difficult to assess. Clearly, most illness does not result in death; simple calculations show, for instance that less than 1 percent of the total cases of pneumonia in a year result in death (Vital and Health *Statistics*, various issues). On the other hand, the treatment of a fatal case is certainly likely to be more expensive than the treatment of a nonfatal case (unless the fatal illness is very short), so fatal illnesses may still account for a significant proportion of medical expenditures. In this case, using total medical expenditures as an estmiate of the benefits of reducing morbidity alone would overstate these benefits.

2.4.3. Individual Versus Societal Willingness to Pay

The analysis so far has focused on COI measures as approximations of an individual's willingness to pay for improvements in his own health risks, but society might also have an interest in the individual's health. The problem of which viewpoint to use, individual or societal, has received attention in the cost of illness literature. Some early researchers, for instance, reported foregone earnings net of consumption, on the grounds that it is the net earnings that society lost due to an individual's morbidity and mortality (see, for instance, Weisbrod (1961, 1971)). The common practice currently is to estimate total earnings fore-gone, which is justified by the relation between total earnings and individual willingness to pay, as discussed above. In other ways, however, the COI studies have continued to try to consider the societal viewpoint. This can be seen in further details of the calculation of foregone earnings. Earnings are estimated gross of taxes, reflecting the value to society of the taxes that would be paid in the absence of illness, though what most likely matters to the individual's utility is his net of tax income. Non-labor income is not included in COI measures of foregone earnings, on the other hand, because though the individual does consume it, it would not be lost to society if the individual suffers morbidity or mortality. In general, the present status of the COI approach might be described as an uneasy compromise between the individual and the societal viewpoints.

Some attempts have been made to reconcile the differences between the individual and the societal viewpoints in measuring the benefits of improved health, though these seem to have concentrated on the case of mortality risks. Landefeld and Seskin (1982) develop an adjusted process to calculate foregone earnings, allowing for the individual's perspective in that earnings are computed net of tax, non-labor income is included, an individual discount rate is used (as opposed to the social discount rate), and a risk-aversion factor is applied. These adjusted foregone earnings estimates are closer theoretically and empirically to the measures estimating individual willingness to pay for a reduction in mortality risks directly. Working in the opposite direction, Bailey (1980) attempts to adjust individual willingness to pay measures to allow for benefits to other persons from the reduction in the risk of an individual's death, and in some ways his methodology is closer to the methodology of the COI approach. He modifies a WTP measure to allow for future direct taxes on labor and future indirect business taxes on labor that would be lost due to an individual's premature mortality, and to allow for direct costs associated with a fatality not borne by the family of the victim.

From the perspective of benefit cost analysis, however, many of the deeper conceptual problems in measuring the differences between individual and societal perceptions of the benefits of

health improvement are not resolved, and in fact seem to have received very little attention in this context. A number of problems involve the role of medical expenditures in benefit estimation when considered from an individual versus a societal point of view. In addition, the existence of paid sick leave allows the possibility of a difference between individual and societal valuations of foregone earnings due to morbidity. Finally, pure altruism plays a part when considering how society in general values an individual's health risks. Each of these problem areas is discussed below, but not at the length or with the rigorous analysis they deserve. It should also be noted that in keeping with the general purpose of this section, only the case of morbidity is considered.

The role of medical expenditures in benefit estimation would be much clearer if the market for medical care were the textbook ideal of a competitive market in the absence of distortions. In this situation, Harberger's basic postulates for benefit cost analysis would apply; in particular it could be assumed that: "(a) the competitive demand price for a given unit measures the value of that unit to the demanders;" and "(b) the competitive supply price for a given unit measures the value of that unit to the supplier" (Harberger (1974)). For the last unit bought and sold, the price observed in the market will be the demand price and the supply price, in this ideal setting. So for a marginal change in the quantity of medical care, the market price represents the value both demanders and suppliers place on that unit, and the change in medical expenditures (price times quantity) is the value of that change appropriate for use in benefit cost analysis, from either an individual or the societal point of view. However, the medical care sector is far from the ideal non-distorted competitive market: there are reasons to believe the market price will not be a good approximation of the value of the last unit to demanders; and there are also reasons to believe that the market price of medical care may diverge from the value of the last unit to the supplier, i.e., the value of the next best alternative use of the resources involved in the production of medical care.

The most obvious reason that the market price of medical care may not reflect the value demanders place on the last unit consumed is the existence of third party payments. Recent figures show that over two thirds of all personal health care expenses are paid for by third parties, including private health insurers, governments, private charities, and industry (Gibson, et al., (1983)). Third party payments drive a wedge between the demand price (the price the demander or consumer sees) and the market price. With third party payments, the value the consumer of medical care places on the last unit may be fairly low, depending upon the portion of the cost he pays. The benefits of an improvement in health to the individual demander will relate only to the possibly small reductions in medical expenses he actually sees in the presence of third party payments. Following the COI approach to measuring benefits, however, all medical expenditures are counted, not just those expenses the individual

incurs. This means that a COI measure may not be comparable to a measure based on individual willingness to pay, unless the savings to a third party payer resulting from an individual's reduced health risks are somehow passed on to the individual, as could be the case if healthier individuals receive reductions in their health insurance premiums. Even if the individual does not perceive the total savings in medical expenditures, though, as a first approximation the COI benefit measure may represent the societal viewpoint, since the third pary payer, or whoever does realize the savings in costs (such as other purchasers of health insurance), do benefit. The sum of the savings to the individual directly involved and the savings to these others will equal the total medical expenditures estimated in the COI approach. This first approximation misses the more subtle effects of the wedge third party payments drive between the demand price and the market price involving optimizing behavior on the part of the demanders. These effects can not be successfully evaluated without developing a more rigorous analytical model of the demand and supply of medical care.

Other ways in which the medical care sector deviates from the ideal competitive market are the importance of non-profit organizations in providing hospital services, and the complicated role the physician plays as both a supplier of medical care, and one who has a possible influence on the quantity of medical care demanded by the patient. In the absence of the profit motive, hospital administrators may pursue other goals, such as a reputation for high quality medical care. If this is the case, hospitals may provide a higher quality, and higher priced, good than the demanders would prefer. The role of the physician could similarly result in the patient consuming more medical care than he would judge optimal if he had full information. So both of these aspects of the medical care sector may drive further wedges between the value of the medical care to the demander, and the market price. Again, a more rigorous analysis is required to make any conclusions about the importance of these possible effects.

A fairly standard analysis can be used in evaluating the importance of one final aspect of the medical care sector: the possible lack of competition in the supply of physician services. Various features of the market for physician services suggest that physicians may have a substantial degree of market power: the effective restriction of entry through the American Medical Association's control of the supply of medical students; the increases over time in the incomes of physicians relative to the incomes of what seem to be comparable professionals; and so forth. In this situation, the market price of medical care will be above the value of the next best alternative use of the resources used in the production of medical care. The difference is an economic rent, or monopoly profit, that is gained by the physicians. Now, a reduction in medical expenditures due to an improvement in health will release resources (physicians) that go to a use valued at less than the market price of medical care. The result is a reduction of the rents received by physicians.

Thus, the decrease in medical expenditures is partly a transfer from physicians to patients. That this tranfer is not a welfare gain for society as whole using the criterion of a potential Pareto improvement described earlier is clear: the gains by the demanders of health care are offset by the losses suffered by physicians. Distributional effects could be relevant, however.

To summarize the preceding discussion of the medical care sector, aspects of the demand and supply of medical care suggest that there may be differences in how the individual and how society value reductions in medical expenditures. Many of the effects are unclear, in the absence of a rigorous analytical model. The clearest result is that if physicians do have some degree of market power, part of the reduction in medical expenditures will represent a transfer of income, and not a gain to society as a whole.

Another case for which the value of a health improvement may be different depending upon the individual or societal viewpoint is the analysis of lost time due to illness if the individual receives paid sick leave. This case has been analyzed by Harrington and Portney (1983) as a variant of their general model. As they note, as a first approximation it might seem that lost time due to illness, though no longer a cost to the individual, still represents a cost to society as a whole: with paid sick leave the employers would perceive the costs associated with a worker's illness. Then if the COI approach estimates foregone earnings without allowing for paid sick leave, the COI benefit measure will diverge from the individual WTP measure, but it will still approximate society's willingness to pay for a health improvement. However, the presence of paid sick leave changes the individual's optimizing behavior, in particular it changes his optimal choice of defensive expenditures, and his ability to trade off leisure time and time spent working. As a result, the formal analysis of Harrington and Portney concludes that with paid sick leave, the COI measure is no longer necessarily a lower bound to the WTP measure. (This is the type of subtle effect that must be considered in a complete analysis of the issues raised earlier involving third party payments and other distortions in the medical care sector.)

The final difference between individual and societal willingness to pay for a reduction in morbidity that will be considered is the possibility of pure altruism. In this case, other members of society are willing to pay for an improvement in an individual's health, and these amounts should be added to the individual WTP measure. Altruistic motives are clearly important, and in particular family members may be willing to pay a great deal to improve the morbidity risks of other members of the family. This explanation may relate to the values placed on improving the morbidity risks to children, infant mortality risks, and even pre-natal care,

2.4.4. Quality of Cost of Illness Estimates

The analysis of sections 2.4.2 and 2.4.3 suggests there may be conceptual problems with the cost of illness approach, because costs of illness may not be closely related to either individual or societal willingness to pay for improved health. Despite these objections, the cost of illness approach remains widely accepted as a standard approach to valuing health. Often, this acceptance is justified by the argument that theoretical considerations aside, the COI benefit measures are easily and reliably estimated in practice. This section addresses directly the issue of the quality of cost of illness estimates, as usually implemented.

The most recent attempt to make a comprehensive estimate of the total costs of illness in the U.S. is the study by Paringer and Berk (1977), for the Fiscal Year 1975. In addition, a comprehensive estimate of personal health expenditures by disease category has been completed by Hodgson and Kopstein (1984), for the year 1980. The health care expenditure estimates of the Hodgson and Kopstein study, combined with the estimates of foregone earnings due to morbidity from the Paringer and Berk study will be an important source of estimates for possible use in benefit cost analysis. (see section 2.2.5, below). For this reason, a review of the quality of these estimates is in order. In addition, since these studies use a standard methodology, their weaknesses and strengths will be shared by a majority of the COI studies.[1]

First, the quality of the estimates of health or medical expenditures due to different diseases is reviewed. Following this is a discussion of the estimates of foregone earnings due to morbidity.

2.4.4.1. Estimates of Health Expenditures

To evaluate the quality of the COI estimates of health expenditures by disease category, it is necessary to review the methodology behind these estimates. The comprehensive studies such as that of Paringer and Berk follow fairly closely the methodology developed by Rice (1966). The starting point is a measure of total health sector expenditures for a given year, E. Then, expenditures are broken down by type of service purchased, i.e. hospital care, physicians' services, etc. Letting E_i represent expenditures in the i^{th} service category, where $i=1,\ldots,n$, note that the sum of the E_i equals E. Estimates of the E_i are available from the Health Care Financing Administration (HCFA). (Before 1978 these estimates were prepared by the Social Security Administration.) Next, the COI studies must estimate a series of weights, v^j_i, which represents the percentage of expenditures in service category i accounted for by disease j. A variety of sources is used to estimate the different v^j_i. Finally, the expenditures necessitated by disease j, E^j, can be computed as the sum of the expenditures

necessitated by disease j.in each of the n service categories. The principle advantage of this methodology is that double counting is avoided, since total expenditures are simply distributed to the different disease categories.

For the purpose of benefit estimation, it is the expenditures necessitated by a particular disease, E^j that are of interest. Since in general the weights for the j^{th} disease will vary across the service categories, proper estimation of the expenditures by service category and the weights is required. In a recent review, Scitovsky (1982) finds problems in both parts of the estimation process.

A serious problem exists in the HCFA definitions of the service categories. The major categories of expenditures are: 1) hospital care, 2) physicians' and other health professionals' services, 3) drugs and medical sundries, 4) nursing home care, and 5) nonpersonal health care services, such as the prepayment and administrative expenses of insurance, medical construction, etc. Currently, the HCFA estimates of hospital expenditures include salaries and other payments to health professionals on hospital staffs, and the expense of drugs dispensed in hospitals. So expenditures for hospital care are overstated, while expenditures for health care professionals' services and for drugs and medical sundries are understated. A similar problem arises in estimating expenditures on nursing home care: these estimates include the costs of drugs dispensed in nursing homes. Redefining the service categories to correct for these problems, Scitovsky presents conservative estimates of the errors in the 1978 HCFA estimates of health care expenditures by service category. She finds that expenditures for hospital services were overstated by 12.4 percent, and expenditures for nursing home care were overstated by 3.5 percent. Expenditures for dentists' services were understated by 1.8 percent, expenditures for physicians' services were understated by 9 percent, and expenditures for drugs and medical sundries were understated by 50 percent.

Scitovsky mentions other problems with the estimation of the size of the service categories, but could not estimate the magnitude of these problems. For instance, expenditures for physicians' services may be further understated, since the estimates are based on tax returns of physicians. Particularly for physicians in private practice, both the opportunity and a strong incentive to underreport income are present, so this is a source of potentially serious error. Another problem is that Scitovsky feels the quality of the data used to estimate expenditures for nursing home care is poor. Hodgson and Meiners (1982) point out a third problem: double-counting of costs may be included in the estimates of expenditures for non-personal health care services. As an example, the costs of construction of new hospital facilities should be reflected in the prices charged for hospital care, so counting these costs in both categories is incorrect. This type of error is necessarily small, however, since expenditures for nonpersonal health care

make up only a small percentage of total expenditures.

One category of expenditures is typically omitted: expenditures in the nonhealth sector necessitated by illness, such as transportation to and from medical providers, special diets, and so forth. These expenditures are conceptually medical expenses, not preventive expenditures, because they follow the incurrence of a disease and do not prevent or lessen the probability of illness. It would be quite difficult to make a comprehensive estimate of these expenditures, since so many different types of goods and services could be involved. In an admittedly incomplete attempt to estimate some of these costs, Mushkin (1979, pp. 384-5) has estimated that including the nonhealth sector costs of illness would increase total expenditure estimates by 10 to 16 percent.

The problems encountered in the estimation of the expenditures by service categories (the Ei) are probably not as serious as the problems of estimating the weights used to assign expenditures to specific illnesses. Based on the criticisms of Scitovsky (1982) and others, the most important problems seem to be those concerning the allocation of the two largest expenditure categories: hospital services and physicians' services.

Most hospital expenditures are for community hospitals. These expenditures are distributed by days of care for each diagnostic group, as estimated from the Hospital Discharge Survey, weighted by expense per patient day. However, several studies by the Institute of Medicine (1977) show that the hospital diagnosis data are imprecise, so the estimate of the days of care by diagnostic group will be imprecise. Another problem is that the inpatient/outpatient mix is not accounted for in the allocation of expenditures. All expenditures are allocated on the basis of days of inpatient care, but these expenditures include a substantial amount of outpatient care. To the extent that the case mix of outpatient care differs from that of inpatient care, costs will be misallocated: the weights v_1, where 1 = hospital expenditures, will be estimated incorrectly.

Computing the weights for allocating expenditures for physicians' services is also problematic. These weights are based on the distribution of physician visits by diagnosis, based on the National Disease and Therapeutic Index, a continuing survey of private medical practice in the U.S. The quality of these diagnostic data is questionable. Scitovsky feels that these data are even less reliable than the similar data for hospitals, while the Institute of Medicine (1981, p. 89) describes the data as more reliable, but less precise due to the smaller sample used in the survey.

A larger problem is that the studies implicitly assume equal charges for all types of physician services. Since in fact a routine office visit is much less expensive than a visit requiring more extensive services or surgery, the weights will be incorrectly computed, and thus the costs of different illnessess

incorrectly estimated. That this is a potentially serious problem can be seen by comparing several estimates of the expenditures due to cancer. Rice and Hodgson (1978) modify Paringer and Berk's assumption of constant costs by breaking down physicians' services into four types with four different costs. Using this procedure, they reach an estimate 85 percent higher than Paringer and Berk's, and they feel that their result is still an understatement. Based on actual observation of patients, Scitovsky and McCall (1976) estimate physicians' services for breast cancer as costing three times more than the Rice and Hodgson estimate, While it is not clear which is the best estimate, there is certainly a very large range in this case. In general, it must be concluded that the estimation of this set of weights, the v_m where m = physicians' services, is also quite imprecise.

Problems also exist in the allocation of expenditures in the remaining smaller service categories: drugs and medical sundries, nursing home care, and nonpersonal health care services. Early studies' treatment of the expenditures for drugs and sundries is poor. The original Rice (1966) study does not allocate these expenditures at all, and the Cooper and Rice (1976) update allocates expenditures without distinguishing between prescription and non-prescription drugs. However, the Paringer and Berk study does make this distinction (see Berk, et al., 1978). Without knowledge of the detailed methodology used in the Hodgson and Kopstein study, it is impossible to assess the accuracy of their estimates of the weights used in the allocation of expenditures for drugs and medical sundries. Scitovsky (1982) found no evaluation of the data in general, and so could not express an opinion regarding its reliability. On the other hand, Scitovsky does judge the data used in allocating expenditures for nursing home care as poor, so the estimates of that set of weights are suspect. Finally, some remaining personal health care expenditures may not be allocated at all; Hodgson and Kopstein were able to allocate all but 5.6 percent of these expenditures. However, no attempt is made to allocate expenditures for nonpersonal health care to specific disease categories. For 1980, this means that an additional 16 percent of total health care expenditures are left unallocated. In effect, this final set of weights, v_n where n = nonpersonal health care, have been arbitrarily set to zero. Hodgson and Meiners (1982) in particular emphasize that these expenditures are a cost of illness and should be allocated by disease category (to the extent they do not represent double-counting, see above).

A serious problem that affects the estimation of all of the weights is the treatment of multiple conditions. The procedure is to allocate all of a patient's expenditures to his primary diagnosis, even though multiple conditions may be present. Multiple conditions seem fairly common. Scitovsky (p. 479) reports studies that 52 percent of hospital patients has multiple conditions, 85.7 percent of all residents in nursing homes has more than one chronic condition, amd 49.5 percent of the civilian noninstitutionalized population reported one or more chronic

conditions, and the average number of conditions per person with a chronic condition was 2.2.

In the context of benefit cost analysis, the proper treatment of multiple conditions will depend upon the exogeneous change being-considered.' For example, Rice (1966) finds that cardiovascular conditions are often secondary causes of disability, and as such increase the costs of treating other illnesses by necessitating longer hospital stays, etc. Counting these extra expenditures as part of the costs of cardiovascular disease would add around 5 percent to Rice's original estimate. For a program that prevented or cured cardiovascular conditions, the savings of the expenditures due to cardiovascular complications would be a legitimate part of the benefit measure. However, a program that prevented the primary illness might also prevent some of the secondary expense, so the expenditures saved could be counted as part of the benefit of that program also. Careful consideration of each program is necessary, to capture all the relevant benefits, but to avoid double-counting of benefits.

Proper treatment of the problem of multiple conditions is also necessary in the estimation of the lost wages caused by illness, since these are commonly assigned only to the primary diagnosis as well.

Taken together, the above criticisms imply that the estimates of health expenditures by disease category are subject to numerous, possibly large, errors. Many of the different categories of expenditures, the E_i, are estimated incorrectly, as are the weights placed on the categories. The fact that several categories are omitted form the final estimate of expenditures by disease might be taken to implythatthe estimates as a whole are conservative lower bounds. It is true that the estimates will sum to less than a true estimate of total expenditures.. However, this does not imply anything about how the individual E^J as estimated will compare to the ideal true value. It is impossible to make any general statements even about the sign of the errors, much less estimate the magnitudes. Consider as an example the estimate of health expenditures created by a chronic illness, that requires a great deal of routine care, but little hospitalization or surgery. Expenditures will be understated, since such a condition would require relatively large non-health sector costs, such as transportation. On the other hand, since the care would be routine, the cost of each office visitwouldbe overstated by the assumption of constant costs for all office visits. Considering the presence or absence of multiple conditions, whether or not the disease necessitates expenditures drugs, nursing home care, and so on further complicates the the issue. All that can be concluded is that the estimate of the expenditures due to such an illness may be incorrect, but by how much or in what direction would be difficult to guess.

2.4.4.2. Estimates of Foregone Earnings

The estimation of foregone earnings due to different diseases is somewhat more straightforward than that of medical expenditures. The methodology of the Paringer and Berk (1977) study is fairly typical. First, the population is broken down into four groups losing wages due to illness: 1) currently employed individuals; 2) individuals keeping house; 3) non-institutionalized individuals unable to work because of ill health; and 4) the institutional population. Within each group, detailed information is used to estimate the amount of earnings foregone, and to allocate these losses to specific diseases.

A general problem of the foregone earnings estimates is that, following the human capital approach, the COI studies focus on output or production lost, be it market, or non-market household production. Thus, the studies attempt to measure days lost from work, or days lost from house-keeping, as a result of illness. This measurement does not capture all the costs that an individual would be willing to pay to avoid. As in the models disucssed above, an individual can be thought of spending his time working, at leisure, or ill. Utility maximizing behavior implies that work and leisure will be traded off until at the margin leisure time is just as valuable as working time. Additional time spent ill, whether it comes out of leisure time or is lost from work, is valued at the wage rate by the individual. By only 'valuing the time actually lost from work or housekeeping, the COI measure of foregone earnings implicitly values leisure time at zero. Compared to the conceptually correct measure, COI estimates like Paringer and Berk's are incomplete.

There are also problems specific to the estimation of the foregone earnings of each of the four groups. The estimation of the foregone earnings due to illness of those currently in the work force is probably the most problem free. The Paringer and Berk study uses unpublished National Center for Health Statistics (NCHS) data on the number of work-loss condition days by age, sex, and diagnosis for individuals in this group. As the NCHS data is based on the the National Health Survey, a household survey, the first set of problems involves the accuracy of these estimates. In their general comments on the quality of data from the Survey, NCHS cautions that the estimates are based on a sample, and not the entire population, so they are subject to sampling error, but adds that sampling errors for most of the estimates are small (see Vital and Health Statistics, various issues).. Another problem is that the results of the Survey depend, of course, on how the respondents report their health status. While the National Health Survey is undoubtedly well-designed, this type of problem is to some extent impossible to eliminate. Cooper and Rice (1976) conclude that the use of Survey data in estimating foregone earnings due to morbidity "undoubtedly results in conservative estimates for some diseases and overstatements for others," because of incorrect identification of the conditions actually present in the

respondents.

A second set of problems encountered in the estimates of the foregone earnings of the currently employed is that it is the number of "condition days" that is reported. A condition day of work-loss is a day of work loss associated with a certain condition, so if an individual reports that he missed a day for two conditions, this would be reported as two condition days of work-loss. In general, the sum of condition days of work-loss may exceed the total number of person days of work-loss. To avoid double counting of work-loss days, Paringer and Berk scale down all work-loss condition days by a constant, so the sum of adjusted work-loss condition days equals the total of person days of work-loss. As they note, "this procedure may create a bias in the estimates of morbidity costs by disease class, since certain classes are more likely to be primary causes of work-loss or bed-disability than others." (Paringer and Berk, 1977, p. 9).

A final source of error in the esimation of the foregone earnings of the currently employed is the specificity of the data used. While the data is age- and sex- specific, the Institute of Medicine (1981, p 91) argues that even more specific data would be desireable. Consider their example that the better educated, who generally have higher earnings, may be healthier than the less well educated, and less likely to fall ill from an exogeneous threat such as pollution. Failure to control for education will result in an overstatement of the foregone earnings due to an increase in illness, since the poorly educated with below average earnings for their age/race/sex group will be affected disproportionately. Variables other than education may also be important, so additional bias may be present in the estimates of the earnings lost by those currently employed.

The estimation of the "foregone earnings" of individuals keeping house is less precise than the estimation for the currently employed. The Paringer and Berk study uses unpublished NCHS data on the number of bed-disability condition days for women keeping house, by age groups. Again, problems may be encountered because of the possible inaccuracies of the Survey data. In addition, the bed-disability condition days are scaled down, so the estimates may be biased as with the work-loss condition days discussed above. Finally, the same biases may result because education and other possibly important variables are not controlled for.

There are further problems with the estimates of the value of housekeeping services. First, the procedure used to value these services is questionable. The values are based on what the Institute of Medicine (1981, p. 91) describes as a "relatively small outdated sample." In addition, time spent housekeeping is valued according to the wage rates of workers in the marketplace performing similar services. What is relevant to the individual keeping house, however, is the wage rate she is giving up by staying out of the market. The IOM suggests that this might be estimated "based on the earnings of working women with similar

characteristics as housewives". Finally, the value of time spent by all individuals keeping house, not just women, should be estimated. While Paringer and Berk (pp. 11-12) make a strong case that this should be done, they only estimate the value of men's housekeeping services (or household production in general) for the case-of mortality. Estimates of the loss of household production due to morbidity are limited to estimates of women's loss.

There is less to say about the estimation of the foregone earnings of those unable to work because of illness and the institutional population. The key assumption made is that these groups would have had the same work and housekeeping experiences as the currently employed, controlling for sex and age. Whether this is a good approximation is not clear, but it is also not clear if any better assumption could be made. This assumption does imply that any biases in the estimation of the foregone earnings of the currently employed and of those keeping house will aslo exist in the estimates of the foregone earnings of those unable to work and the institutional population.

A recent study by Salkever (1985) includes several methodological refinements in the estimation of foregone earnings due to morbidity and so avoids some of the problems outlined above. Salkever develops estimates for foregone earnings for non-institutionalized males age 17 to 64 by combining data from the Health Interview Survey (HIS) and the 1976 Survey of Income and Education (SIE). To compute the earnings loss for each work loss day reported in the HIS, a synthetic estimate of the respondent's hourly wage was computed. This entailed inserting data on the respondent's personal character-istics from the HIS into an hourly wage regression estimated with SIE data. The independent variables included measures of the individual's education, presence or absence of a chronic condition, region and urban or rural character of residence, industry where person was employed and average earnings for the occupation in which the person was employed. Using such specific data on the individuals who suffer work loss days implies that Salkever's estimates of foregone earnings are much less likely to suffer the bias problems the Institute of Medicine described. To return to the IOM example, since education differences are controlled for in Salkever's estimates, foregone earnings will not be overstated even if the better educated earn more and are less likely to be sick, as the IOM suggests.

Salkever also estimates the earnings losses for persons unable to work because of illness. As in earlier studies, he assumes these persons lose income equal to the earnings of similar individuals without chronic health problems. Specifically, these foregone earnings were computed as the average earnings by persons in the SIE data, without chronic health problems, classified by age group, education level, race and region of residence. Just as for valuing work loss days, using more specific data on the individuals unable to work because of illness means that Salkever's estimates are less

likely to be biased.

Salkever's estimates of foregone earnings due to morbidity represent important improvements in methodology, which should be relfected in improved accuracy. However, since Salkever only develops estimates for males age 17 to 64 for certain conditions, his estimates are not directly comparable to the more comprehensive estimates of earlier studies reported below. As a result, it is difficult to judge the empirical importance of either Salkever's refinements or the inaccuracies implied by the earlier methodology.

In conclusion, the estimation of the foregone earnings due to illness may be straightforward, but the estimates still are not necessarily very close to the ideal true values. Most of the errors tend to understate foregone earnings due to morbidity, so in this case, unlike the health expenditures estimates, the existing estimates can be considered as conservative lower bounds to the true values.

2.4.5. Empirical Estimates of the Cost of Illness

In this section, estimates of medical expenditures and foregone earnings due to illness are presented, to be used as a measure of the value of improved morbidity risks. Particular emphasis is placed on the cost of illness estimates for diseases and disease categories that might be related to environmental quality. In section 2.4.5.1, some estimates from existing COI studies of the total medical expenditures and foregone earnings to morbidity related to different disease categories are presented. In section 2.4.5.2, these estimates are put on a per case basis, and additional per case estimates are presented. In section 2.4.5.3, for certain conditions, the costs are also expressed on a per day of illness basis.

2.4.5.1. Total Medical Expenditures and Foregone Earnings Due to Morbidity

Reported in Table 2-4 are total figures for medical expenditures and foregone earnings due to morbidity caused by various diseases or disease groups. The totals have all been updated to August 1984 dollars, using the medical care component of the CPI to adjust the medical expenditures, and the general CPI to adjust foregone earnings. It is recognized that this procedure may introduce errors in the estimates, due to relative price changes in health care services and relative wage changes for different age/sex/race groups.

In addition to the comprehensive estimates of the cost of all illnesses of the Paringer and Berk and the Hodgson and Kopstein studies, Table 2-4 also reports the results of studies that estimate the costs of a specific illness or group of

illnesses.[2] These studies are useful in two ways. First, the expenditures and earnings lost. due to a specific illness (e.g. emphysema) can be found. Comprehensive studies only provide estimates relating to more general categories (e.g., all respiratory diseases). Second, the specific illness studies may employ a different methodology. This is particularly relevant for the estimates of health expenditures. While some studies use the same methods and data sources as the comprehensive studies, others estimate expenditures based on more disaggregated data, such as the observation of actual cases. For a review of the methodology and quality of over 200 studies that estimate the costs of illness, see Hu and Sandifer (1981). Briefly, the studies by the National Heart and Lung Institute (NHLI (1972, 1975)) and the Acton (1975) study follow essentially the same methodology as the Paringer and Berk (1975) and the Hodgson and Kopstein (1984) studies, as reviewed above in Section 2.4.4. The study by Freeman, et al., (1975) represents a slightly different methodology (and it is thus notable the close correspondence of the Freeman estimates and the NHLI (1972) estimates of the cost of emphysema). The Hartunian, et al., (1980) follows a methodology followin, an incidence-based approach to measuring medical expenditures.[4]

It is difficult to make many general statements concerning the range of estimates presented in Table 2-4. It is clear that the estimates from the Paringer and Berk and the Hodgson and Kopstein studies are much higher than comparable estimates from other studies. This seems to be part of a general trend that the more recent estimates are higher than estimates based on an earlier time period and scaled up for inflation. Two influences seem important. First, the use of the medical care component of the CPI and the general CPI in adjusting for inflation may somehow be biasing the earlier estimates downward. Second, the more recent studies may be a more complete accounting of costs, reflecting improvements in methodology and data sources. For instance, more expenditures are allocated by disease in the more recent studies, and more allowance is made for household production in the estimation of foregone earnings. For these reasons, .it is likely that the more recent estimates are more accurate, and whenever possible that most recent study should be used to provide estimates for use in benefit cost analysis.

TABLE 2-4: TOTAL MEDICAL EXPENDITURES AND FOREGONE EARNINGS DUE TO SELECTED ILLNESSES

(in million $, August 1984)

Disease Category	Medical Expenditures	Foregone Earnings
All diseases		
Hodgson and Kopstein (1984)	315,058	
Paringer and Berk (1977)		112,319
Infective and Parisitic Diseases		
Hodgson and Kopstein (1984)	6,459	
Paringer and Berk (1977)		3.024
Neoplasms (cancer)		
Hodgson and Kopstein (1984)	19,563	
Paringer and Berk (1977)		2,144
Hartunian, et al. (1980)	14,522	
Diseases of the Circulatory System		
All		
Hodgson and Kopstein (1984)	47,652	
Paringer and Berk (1977)		16,963
Acton (1975)	14,557	10,557

TABLE 2-4 (continued)

Disease Category	Medical Expenditures	Foregone Earnings
Cerebreovascular Disease (Stroke)		
Hodgson and Kopstein (1984)	7,324	
Paringer and Berk (1977)		685
Hartunian, et al. (1980)	5,364	
Acton (1975)	2,201	1,132
NHLI (1975)	3,789	735
Coronary Heart Disease		
Hartunian, et al. (1980)	5,642	
Acton (1975)	5,871	5,416
NHLI (1975)	7,912	1,157
Respiratory Diseases		
All		
Hodgson and Kopstein (1984)	24,850	
Paringer and Berk (1977)		16,572
NHLI (1972)	6,385	4,284
Emphysema		
NHLI (1972)	652	1,414
Freeman, et al. (1976)	579	3,610

2.4.5.2. Per Case Estimates of Medical Expenditures and Foregone Earnings Due to Morbidity

Table 2-5 reports per case estimates of medical expenditures are foregone earnings due to various illnesses. The estimates are based on the same sources as the totals of Table 2-4. In addition, independent per case estimates by Scitovsky and McCall (1976) and Acton (1975) are presented. All estimates are updated to August 1984 dollars (See Notes to Table 2-6 for details).

In putting the total figures on a per case basis, the basic procedure is simply to divide the total cost figure for ayearby the appropriate number of cases of that illness in that year. The proper measurement of the appropriate number of cases is not simple, however. In defining what constitutes a "case" of an illness, the specific use of the per case estimates in benefit cost analysis must be considered. For instance, it might be known from epidemiologic or health econometric studies that a reduction in pollution will reduce the number of serious cases of a particular disease, i.e. only those cases that involve medical expenditures and foregone earnings. In this situation, in preparing per case estimates it would thus be desirable to define a case as only a case of the disease that does involve medical expenditures and foregone earnings. Instead, it might be known only that the reduction in pollution will reduce the number of cases of a particular disease, without specifying if the cases are serious or not. Under these circumstances, a more general definition of case is desirable, allowing for cases involving varying amounts of medical expenditures and foregone earnings to be included. Essentially, the per case estimates of medical expenditures and foregone earnings represent the average cost of a case of disease, but what population over which to average is somewhat ambiguous. The per case estimates of Table 2-5 are prepared using a broad definition of the number of cases, so the average medical expenditures and foregone earnings due to a case of illness are conservative estimates.

The source of the data for the number of cases of acute and chronic illnesses (except neoplasms) is the National Health Survey, as reported by the National Center for Health.Statistics (NCHS) in various issues of Vital and Health Statistics As described above, the estimates from the survey are subject to possible inaccuracies. Estimates of the number of cases of the different illnesses may understate the actual number of cases, in general. For acute cases, the estimates exclude all conditons involving neither restricted activity nor medical attention. For chronic cases, data is available on the degree of impact the illness had, so the number of cases could be adjusted downward so that only more severe cases are counted. However, the fact that chronic illnesses are generally under-reported in surveys, and the likely use of' the per case estimates in benefit cost analysis of changes in all types of cases of illness argue forthebroader measure of chronic cases to be used.

An additional problem encountered in estimating the number of cases of chronic illnesses is encountered in that the prevalence of chronic conditions is not estimated for every year. The prevalence estimates used in preparing Table 2-5 are estimates from the survey for the closest year to the year used as a base for the different studies that report total medical expenditures and foregone earnings due to morbidity.

Estimating the number of cases of neoplasms (cancer) presents several special problems. Three different measurements are possible candidates. First, the incidence of cancer, that is, the number of new cases of cancer diagnosed in a given year, could be used, Second, the number of individuals under medical care for cancer is a possible measure of the number of cases of cancer existing in a given year. Third, by combining incidence and survival data, it is possible to estimate the number of people alive in a given year with a history of cancer. The incidence measurement is an understatement of the number of cases of cancer, since in any given year there will be individuals with cancer that was incurred and diagnosed in an earlier year. The number of people alive with a history of cancer is an overstatement, because it includes individuals who for all practical purposes have been totally cured of cancer. So the figure used in preparing Table 2-5 is the number of individuals under medical care for cancer, for 1974 (Cancer Facts and Figures, 1974), though the measure is not exactly comparable to the broader definitions of cases used for other illnesses. Added to this figure is an estimate of the prevalence of neoplasms of the skin, from NCHS estimates. It should be pointed out that adding neoplasms of the skin doubles the number of cases of cancer, and biases the per case estimates of the medical expenditures and foregone earnings due to cancer downwards, since neoplasms of the skin are likely to involve lower medical expenditures and foregone earnings than other cancers. This is an example of the inaccuracies involved in using estimates of the costs of broad groups of illness, such as cancer, as opposed to an estimate of the cost due to a more specific illness, such as a particular type of cancer.

The basic procedure for deriving per case estimates described above is not applied to the totals from the study by Hartunian et al.(1981). This study follows an incidence based approach to estimating the costs of illness, while the other studies cited follow a prevalence based approach. A problem of comparability results. On an aggregate basis, incidence based estimates and prevalence based estimates may be approximately the same; in fact, Hartunian et al.(1980) find relatively small differences between the two approaches for some conditions. However, putting the prevalence based estimates on a per case basis yields estimates of the average yearly costs of a case of illness. In contrast, expressing incidence based estimates on this same basis would yield estimates of the average lifetime costs of a case of illness. A second problem is that expressing the total incidence based estimates of costs would entail

dividing total costs by the incidence of the different conditions, and estimates of incidence are limited in scope and accuracy.[4]

The per case estimates due to Hartunian et al. reported in Table 2-5 are estimates of the average first year costs of several conditions. The estimates are derived from the details given of the calculation of the total costs in Hartunian etal. (1981, various chapters). Since detailed descriptions of the calculations were only given for selected conditions to be illustrative of the methodology, the number of conditions for which first year costs can be estimated is limited.

In addition to the per case estimates derived from studies estimating total medical expenditures and foregone earnings, Table 2-5 includes per case estimates from two independent sources. Scitovsky and McCall (1976, as cited in Mushkin (1979)) report average medical expenditures due to several conditions, based on the cost of care in the Palo Alto Medical Clinic in 1971 actually incurred by patients. Estimates of per case medical expenditures and foregone earnings derived from Acton (1975, tables 7 and 9) are also presented. In what is described as an illustrative exercise, Acton puts his total estimates of the costs of various diseases of the circulatory system on a per case basis using a procedure similar to that described above. The important difference is that Acton attempts to estimate the medical expenses and foregone earnings of an average person actively suffering the consequences of a disease. That is, Acton uses a narrower definition of a "case" of a disease than is used in the preparation of the other per case estimates of Table 2-5.

While Table 2-5 may seem to include a very wide range of estimates, considering truly comparable diseases shows some agreement between the studies. The lowest estimates of medical expenditures and foregone earnings per case are for all respiratory diseases ($87 and $56, respectively), and for all infective and parasitic diseases ($123 and $63). However, the per case figures for all respiratory diseases are influenced by the very large number of cases of upper respiratory tract infections that presumably involve relatively low medical expenditures and foregone earnings. The estimates of the medical expenditures and foregone earnings due to a more serious respiratory disease such as emphysema are substantially higher ($497 and $1,078 from NHLI, or $441 and $2,753 from Freeman, et al.). A similar result holds when comparing the cost of cases of diseases of the circulatory system. The per case estimates for all diseases of the circulatory system are much smaller than the per case estimates for specific, more serious diseases, such as cerebreovascular disease (stroke), coronary heart disease, and myocardial infarction. The different estimates for these specific diseases show more agreement between studies, but there is still a fairly wide range. For instance, Acton estimates the medical expenditures due to a stroke as $1,561, while the per case estimate based on Hodgson and Kopstein is $4,210. As noted above, Acton uses a lower estimate of the number of cases in

expressing his results on a per case baiss, which implies that if the Acton and the Hodgson and Kopstein estimates were computed in exactly the same manner, the difference would be even greater. This difference in the medical expenditures due to a case of stroke is the most extreme difference found in Table 2-5 for a specific disease; in general the per case estimates based on different studies' estimates of the medical expenditures and foregone earnings for a specific illness are much closer together.

To sum up, in using the per case estimates of Table 2-5 in benefit cost analysis, two considerations should be kept in mind. First, just as for the estimates of the totals in Table 2-4, the per case estimates in Table 2-5 based on the most recent studies are judged as generally superior in quality. Second, the estimates of the costs of a specific disease should be used rather than the estimates of the costs of a group of diseases, whenever possible.

TABLE 2-5: PER CASE MEDICAL EXPENDITURES AND FOREGONE EARNINGS

(in $, August 1984)

Disease Category	Medical Expenditures Per Case	Foregone Earnings Per Case
Infective and Parasitic Diseases		
Hodgson and Kopstein (1984)	123	
Paringer and Berk (1977)		63
Neoplasms		
All		
Hodgson and Kopstein (1984)	8,780	
Paringer and Berk (1977)		962
Lung Cancer		
Hartunian, et al. (1981)	15,687	13,404
Cancer of the Breast		
Scitovsky and McCall (1976)	7,605	
Diseases of the Circulatory System		
All		
Hodgson and Kopstein (1984)	773	
Paringer and Berk (1977)		275
Cerebreovascular Disease (Stroke)		
Hodgson and Kopstein (1984)	4,210	
Paringer and Berk (1977)		394
NHLI (1975)	3,708	1,318
Acton (1975)	1,561	803

TABLE 2-5 (continued)

Disease Category	Medical Expenditures Per Case	Foregone Earnings Per Case
Coronary Heart Disease		
NHLI (1975)	2,393	350
Acton (1975)	1,406	1,297
Angina Pectoris		
Hartunian, et al. (1980)	246	0
Myocardial Infarction		
Scitovsky and McCall (1976)	11,242	
Respiratory Diseases		
All		
Hodgson and Kopstein (1984)	87	
Paringer and Berk (1977)		56
NHLI (1967)	25	17
Emphysema		
NHLI (1967)	497	1,078
Freeman, et al. (1976)	441	2,753
Pneumonia (non-hospital care)		
Scitovsky and McCall (1976)	253	

TABLE 2-6: PART 1
PER CASE MEDICAL EXPENDITURES
(background for Table 2-5)

Disease Category and Study	Total Costs (in millions)	Number of Cases (in thousands)	Per Case costs (year varies)	Per Case costs (August 1984)
Infective and Parasitic Diseases				
Hodgson and Kopstein (1984)	4,498	52,691	85.37	123
Neoplasms				
Hodgson and Kopstein (1984)	13,623	2,228	6114.5	8,780
Diseases of the Circulatory System				
All				
Hodgson and Kopstein (1984)	33,184	61,652	538	773
Stroke				
Hodgson and Kopstein (1984)	5,100	1,740	2,931	4,210
NHLI (1975)	971	1,534	633	3,708

TABLE 2-6; PART 1 (continued)

Disease Category and Study	Total Costs (in millions)	Number of Cases (in thousands)	Per Case costs (year varies)	Per Case costs (August 1984)
Coronary Heart Disease				
NHLI (1975)	2,072	3,307	627	2,393
Repiratory Diseases				
All				
Hodgson and Kopstein (1984)	17,305	285,323	60.65	87
NHLI (1967)	1,672	258,473	6.47	25
Emphysema				
NHLI (1967)	171	1,313	130.24	497
Freeman, et al. (1976)	183	1,313	139.5	441

TABLE 2-6: PART 2
PER CASE FOREGONE EARNINGS

Disease Category and Study	Total Costs (in millions)	Number of Cases (in thousands)	Per Case costs (year varies)	Per Case costs (August 1984)
Infective and Parasitic Diseases				
Paringer and Berk (1977)	1,559	48,206	32.34	63
Neoplasms				
Paringer and Berk (1977)	1,105	2,228	496	962
Diseases of the Circulatory System				
All				
Paringer and Berk (1977)	8,744	61,652	141.8	275
Stroke				
Paringer and Berk (1977)	353	1,740	203	394
NHLI (1975)	421	1,534	274	1,318
Coronary Heart Disease				
NHLI (1975)	370	3,307	112	350
Respiratory Diseases				
All				
Paringer and Berk (1977)	8,542	285,323	28.75	56
NHLI (1967)	1,370	258,473	5.3	17

Emphysema

NHLI (1967)	452	1,313	344.25	1,078
Freeman, et al. (1976)	1,343	1,313	1,023	2,753

Explanatory Notes For Table 2-6

1. Total costs (in millions) are the original estimates of the various studies of the total medical expenditures and foregone earnings. These estimates are for various years.

2. Number of cases (in thousands) is the sum of the incidence of acute cases and the prevalence of chronic cases, for the year closest to the year the studies estimated that could be found. Source: Vital and Health Statistics, various issues.

3. Per case costs = total costs divided by number of cases. These per case costs are for the years of the original studies.

4. Per case costs (Aug. 1984) are the previous per case costs expressed in current (Aug. 1984) dollars; medical expenditures are adjusted using the medical care component of the CPI; foregone earnings are adjusted using the general CPI.

2.4.5.3. Estimates of the Costs of Illness per Day Spent Ill

The third column of Table 2-7 presents estimates of the costs of various illnesses per day spent ill. These estimates are derived by dividing the per case costs developed above by the average number of days spent ill per case of illness per year. In the first column of Table 2-7 are per case costs of illness (medical expenditures plus foregone earnings) from Table 2-6. Estimates of the average number of Restricted Activity Days (RADs) are available from the Health Interview Survey for most acute conditions and certain chronic conditions. These estimates are presented in column two of Table 2-7.

Costs of different illnesses per day spent ill present a fairly narrow range, from $10 to $81. This reflects the fact that a great deal of the difference between a minor and a serious illness is simply the average number of days spent ill: the number of days per condtion varies from about 4 for an average case of acute infective and parasitic disease or for an acute respiratory disease, to over 40 days spent ill due to heart disease. Another possible difference is the degree of disability on the day spent ill. A Restricted Activity Day is defined as "one on which a person substantially reduces his normal activity for the whole day due to an illness or injury" (Vital and Health Statistics), this can range from reduced activity alone to a day of work loss to a day of bed disability. The RADs for the more serious conditions may reflect a greater restriction of activity than the RADs for the minor conditions.

TABLE 2-7: COSTS OF ILLNESS PER DAY SPENT ILL

(in $, August 1984)

Disease Category	costs Per Case	RADs Per Case Per Year	costs Per RAD
Infective and Parasitic Diseases			
Hodgson and Kopstein (1984)	186	4.06	46
Paringer and Berk (1977)			
Diseases of the Circulatory System			
Coronary Heart Disease			
NHLI (1975)	2743	43.1	64
Acton (1975)	2703	43.1	63
Respiratory Diseases			
All			
Hodgson and Kopstein (1984)	143	4.1	35
Paringer and Berk (1977)			
NHLI (1967)	42	4.1	10
Emphysema			
NHLI (1967)	1575	35.8	44
Freeman, et al. (1976)	3194	35.8	89
Pneumonia (non-hospital care)			
Scitovsky and McCall (1976)	253	18	14

2.4.6. Concluding Remarks on the Cost of Illness Approach

Section 2.4 is concerned with the problems of valuing changes in health risks as reduction in health expenditures and foregone earnings, i.e., the cost of illness approach. A contribution of the present project has been to put aggregate costs of illness on an individual per case and per day spent ill basis. Results indicate that a typical case of acute respiratory disease involves $87 of medical expenditures, and $56 of foregone earnings. A case of emphysema involves $441 of medical expenditures, and $2,753 of foregone earnings. A day spent ill due to a typical case of acute respiratory illness costs $35, while a day spent ill due to emphysema implies costs of $89. Estimates of this kind on an individual basis needed to evaluate environmental policy changes have not been available heretofore.

The cost of illness approach is an important source of estimates for the value of health, because it is commonly accepted by many researchers in the health care fields, and it provides estimates for the value of a wide range of health effects. Therefore, section 2.4 includes a careful evaluation of the approach to assess its usefulness and accuracy.

This evaluation reveals that the approach suffers from conceptual and methodological shortcomings, which limit its usefulness. One set of issues essentially raises the problem that the cost of illness benefit measure is not well-related to the conceptually correct willingness to pay measure. The discussion of this problem (section 2.4.2) suggests that a cost of illness measure may be a lower bound to a willingness to pay measure. It is not necessarily a good approximation to the willingness to pay measure, however. In addition, the distinction between individual and societal willingness to pay has been treated unevenly in the cost of illness approach, and deserves further consideration.

The review of the methodology of the cost of illness approach in section 2.4.4 leads to the conclusion that the estimates of medical expenditures and foregone earnings due to morbidity are not particularly precise or reliable. This is especially significant since it is the presumed practical advantages of calculating medical expenditures and foregone earnings, instead of calculating willingness to pay, that is often the stated reason for preferring the cost of illness approach.

2.2.10. Footnotes

1. The Paringer and Berk (1977) study is cited by Mushkin (1979), and is part of a series of estimates of the cost of illness for the years 1900, 1930, 1975, and projected for the year 2000, prepared at Georgetown University Public Services Laboratory.

All details of the methodology of Hodgson and Kopstein (1984) study are not described in the published article. They state that their "methodology follows closely that originally devised by Cooper and Rice (1976) to allocate expenditures among diagnoses, amended to include several additional sources of data." My discussion and criticism of the quality of the estimation of health care expenditures is based on the Cooper and Rice methodology, so most of it should apply to the Hodgson and Kopstein study. Since Hodgson and Kopstein do use new sources of data, it is expected that their estimates will be superior to earlier estimates, and some of the criticisms below may not apply.

2. As explained earlier, the Paringer and Berk and Hodgson and Kopstein studies are used because they represent the most recent estimates of foregone earnings and medical expenditures due to illness that could be found.

3. The Hartunian et al. study reports foregone earnings due to morbidity and mortality combined, so the foregone earnings due to morbidity alone could not be derived easily. For this reason, only the estimates of medical expenditures from this study are reported in Table 2-4.

4. For a more complete discussion of the difference between prevalence based and incidence based estimates of the cost of illness, a report is available upon request.

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